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Package Treatment Plants Operations Manual

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PACKAGE TREATMENT PLANTS

operations manual

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OFFICE OF WATER PROGRAM OPERATIONS
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This manual is designed to give the operator an increased knowledge of the basics and aid in effective operation of a package treatment plant. It is also directed to the plant owner and the design engineer. It contains detailed descriptions of the duties and responsibilities of the owner. For the engineer, the purposes are two-fold. It provides additional information that can be used wholly or in part with an O&M manual written for a specific plant. In addition, it can aid the consulting engineer in the selection of a plant by pojnting out design problems found in some package plants.

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OPERATIONS MANUAL

PACKAGE TREATMENT PLANTS

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INTRODUCTION

Package treatment plants were originally designed to serve areas that could not be easily connected to an existing sewage treatment plant. Such areas include the subdivisions that began springing up in the fifties and commercial establishments such as restaurants, motels, and parks. More recently, package plants have increased to a size that can serve small municipalities. Many were sold with the idea that the plants would operate themselves and, therefore, could be turned on and forgotten. However, to meet today's more demanding pollution discharge regulations, these plants require daily attention by a knowledgeable and conscientious operator. In addition, the new operator needs time to familiarize himself with the plant. This manual is designed to give the operator an increased knowledge of the basics and aid in effective operation of a package treatment plant.

Some problems in operation of the package plant may be beyond the ability of the operator to control and are too detailed to be presented in this manual. The operator should learn to identify and define these problems in order to turn to someone for outside help. **Outside help** may be the operator's consulting engineer, the operator of the treatment plant in a nearby town, or an engineer from the State Pollution Control Agency. One possible solution may be for several package plant owners to pool resources and provide an areawide management person to be called in for consultation on special problems.

Besides the treatment plant operator, this manual is also directed to the plant owner and the design engineer.

The owner is either the actual purchaser of the plant if privately owned or the individual or group responsible for making policy decisions concerning the treatment plant; such as a city council.

The owner is responsible for adding to the treatment plant when needed, controlling sewer construction practices in the service area, keeping supplies at the plant and supervising the operator. Most importantly, the owner is ultimately, legally, and administratively responsible for the performance of the treatment plant.

For detailed descriptions of the duties and responsibilities of the owner, the reader should refer to Part III, Section 3 – Plant Management.

For the engineer, the purposes of this manual are two-fold. It provides additional information that can be used wholly or in part with an O&M manual written for a specific plant. In addition, it can aid the consulting engineer in the selection of a plant by pointing out design problems found in some package plants.

Many of these problems and actions that operators have taken to overcome them are covered in the section on Case Histories.

HOW TO USE THE MANUAL

This manual is intended to be a handy reference for operation of a biological package treatment system. For detailed maintenance procedures, the operator should refer to the manufacturer's recommendations or other sources such as the plant operation and maintenance manual.

HOW DOES IT WORK?

The manual is divided into three parts, each with a different use. For example:

1. For a solution to a specific problem go to the Troubleshooting section of Part I. Part I also tells how to operate the plant through daily attendance.

2. Have a question on how the treatment plant works? Go to the Basics in Part II.

3. Part III has useful information on Case Histories, Safety and Emergencies, and Plant Management. It also contains the Appendices.

How to Find Your Way Around

Part I assumes that the reader is familiar with the process of biological wastewater treatment. If not, check out Part II on the Basics for a quick review.

Part I—Operations

I-1 Plant Survey—Tells what the treatment plant operator should be observing in the way of sight, sound, and odor upon first reaching the plant.

I-2 Observations—A detailed discussion of the different parts of the treatment plant and the things the operator can learn about the condition of the plant by observing them. For example, if there is a lot of foam on the aeration tank, this section will tell why it is there.

I-3 Operational Tests and Interpretations—A discussion of some of the basic tests to keep a plant in proper operation. Additional tests will probably be required by the National Pollution Discharge Elimination System (NPDES) permit and the type and number vary from state to state. Therefore, references are included so the operator can find the correct laboratory procedure for these tests.

This section should be used in conjunction with Section I-6 to confirm any observations obtained on plant inspection. The following section on Operational Procedures should then be used as guidance in implementing changes in plant operation.

I-4 Operational Procedures—The section with the instructions—what we always fail to read. Need we say more?

I-5 Final Plant Survey—A sort of wrap-up tour of the plant before leaving.

I-6 Laboratory Procedures—Actual laboratory instructions for the basic tests discussed in Section I-3.

I-7 Troubleshooting—Information on what to do or where to go to correct an operational problem.

I-8 Plant Checklist—A handy checkoff list of things to do each time the plant is visited.

Part II—Basics

Some of the things you already know are listed in this part along with some things you possibly don't know. Simplified diagrams illustrate specific ideas and equipment. This will be of special benefit to new operators. The **bold type** is used to place emphasis on certain words found in the Glossary in the Appendix.

Part III—Potpourri

This part includes information which will be helpful to the operator, but may not be part of day to day operation. Several of the items located here are Case Histories, Safety and Emergencies, Plant Management, and Appendices.

NOW . . .

You have some idea of what's inside. Flip through the pages, get acquainted with the way the Troubleshooting Guide 4 works, review the Basics, if necessary. Use it in the way that best fits your needs.

FINALLY . . .

Remember that conditions, arrangement, and equipment will vary from plant to plant depending on factors such as design, load, or waste. The values presented are typical, but may vary. See how the contents relate to what you have in your own treatment plant.

After that is done, go to the section or sections that will help answer any questions raised.

Most of all—don't try to read the manual cover to cover—pick the parts that interest you and can help you the most.

PART 1

OPERATIONS

SECTION 1

PLANT SURVEY

Part I is intended to present a suggested plan of operation for the operator as if he pulls up to the plant in his pickup, opens the front gate, and starts his daily duties after being away from the plant for 16 hours or more.

Sight, sound, smell, and touch are the senses the operator must learn to use in making a quick inspection of the plant. Close observation of the plant during normal operation will enable the operator to identify during the plant survey any possible problems.

Problem Areas

What are these possible problems?

Some of the things to take note of are:

1. Does everything look right? Is there any evidence of vandalism, high flows, foaming tanks, or other visual signs or problems.

2. A plant has a characteristic sound while operating. If this is not evident upon arrival, possibly something has gone wrong mechanically.

3. As with sound. the treatment plant should have a characteristic but not unpleasant smell. An abnormal, unpleasant odor may indicate problems.

4. Are the motor bearings too hot to touch? The operator with experience will learn the "feel" of housings covering moving parts so that any unusual vibration or temperature change will be noticed.

By making use of the senses to notice the possible problems, the operator should be able to verify quickly that everything is working properly.

Problems—Yes?

What should be done if problems exist?

If problems should appear, the operator must locate the source of the problem and determine if outside help is needed. The goal is to return the plant to proper operation as soon as possible—no matter how large or small the problem. If the trouble is in the treatment process, either mechanically or biologically, the section on troubleshooting will be helpful in correcting the problem.

Problems—No?

What is done if no problems exist?

If everything appears to be operating normally upon initial inspection, the operator should continue with the routine operation and maintenance procedures outlined in the following sections.

To organize the daily duties, the plant operator is encouraged to develop an outline based on the topics covered in this and following sections. It should include a checklist similar to the one presented in Section 8 so that the operator will not overlook certain areas in his or her daily duties. It will also be helpful if someone less familiar with the plant is called in to work during the regular operator's absence.

A Note to the Consultant

(Consulting engineers using this manual to supplement specific plant manuals are encouraged to review the plant layout, equipment, and type of operation in comparison with the sequence of events presented. A schedule for the operator to follow, naming equipment that he has in his plant, will be a valuable tool both for his use and any others that have responsibility of the plant in his absence.)

SECTION 2

OBSERVATIONS

PRETREATMENT

Walking around the plant following the normal flow route gives the operator an idea of the type of wastewater the plant has received since the last visit. Following are some of the indicators.

Odor

How are odors controlled?

Odors in the area may indicate evidence of septic sewage, scum buildup, or a strong industrial waste in the wastewater. If so, a temporary solution is to wash down the entire area to remove the scum. If grease or industrial waste becomes a problem, the operator should locate the source and attempt to control it at its source through the use of existing ordinances or discussions with the contributor.

Other sources of the odor may be an accumulation of rags and other debris on the comminutor or bar screen. Frequent removal (twice daily) and daily disposal by burying will help to control the odor.

Color

What does a black influent color and septic odor tell?

The color of the influent tells a lot about the waste. A black color accompanied by a septic odor may indicate that part of the wastewater is staying in level sewer lines during low flow periods. The low flow results in solids settling out and slowing down the flow. Manholes should be inspected for the buildup of sludge and/or sand. These lines and manholes require periodic flushing. A source of information on how to locate and flush the lines is:

Handbook for Sewer System Evaluation and Rehabilitation

Publication No. EPA 430/9-75-021, December, 1975, MCD-19

Available from:

General Services Administration (8 FFS)
Centralized Mailing List Services
Building 41, Denver Federal Center
Denver, Colorado 80225

Silt in lines?

A reddish or brown color may indicate silt getting into the lines which, in turn, increases the wear on and requires more frequent maintenance of pumps and other mechanical items. Source of the silt may be a broken line or a side sewer excavation.

Visual

What does a "high-water mark" indicate?

A high-water mark greater than normal in the inlet channel may indicate a high flow during operator's absence or plugging downstream in the bar screen or comminutor. These areas should be checked for proper operation. Comminutor blades may be dull and may not be providing good cutting action.

AERATION TANK

Turbulence

How to tell if complete mixing is occurring.

The operator should observe the entire aeration tank surface for turbulence. Though some of his conclusions will be based on past experience, the extent of surface activity will show if the contents are thoroughly mixed throughout the entire aeration tank. Watching the surface for dead spots will tell if mixing is the same throughout the aeration tanks.

An equipment modification for eliminating dead spots in the aeration tank is shown in the Case Histories section.

The operator should raise or lower air usage based on Dissolved Oxygen (DO) readings. See Section 4—Operational Procedures for information on proper DO levels in the aeration basin.

What may cause low DO?

If the DO does not increase above 1.0 when all aeration equipment is operating, it may be due to plugged air lines, blower not sized right, or high strength waste. If normal air feed fails to raise DO over a 24-hour period, a further check of the mechanical air system may be needed.

Surface Foam and Scum

What type of foam should be present?

The type of foam or scum, if any, on the aeration tank surface, and to a lesser extent, the color of the mixed liquor gives the operator a clue to how well the process is working.

Fresh, Crisp, White Foam: Only a modest accumulation of white, or at least light colored, crisp appearing foam is usually present on aeration tank surfaces when an excellent final effluent is produced. The operator should take note of the conditions in the process and keep them within these ranges because whatever is happening is just right.

Excessive, Billowing White Foam: If the aeration tanks are covered by thick billows of white sudsy foam, the operator can be quite certain that the sludge is too young and that sludge age should be increased by reducing the sludge wasting rate.

Operators who have actually gone through this white foam cycle realize that not all foam is caused by detergents.

What causes thick dark foam?

Thick, Scummy, Dark Tank Foam: At the other extreme, the operator may observe a dense and somewhat greasy scummy layer of deep tan to brown foam covering the entire aeration tank surface. Such foam almost always indicates that the sludge is too old and possibly overoxidized. In this case, the answer is to increase sludge wasting rates. Here again, the sludge wasting rate should usually be increased gradually, possibly 20 percent of return rate per day, on a day-to-day basis while watching the graph plot to see how the changes affect the effluent and mixed liquor solids.

What do hydrogen sulfide odors mean?

Sludge Color and Odor: At times a poor quality, extremely dark brown colored sludge, releasing hydrogen sulfide odors may be seen in the aeration tanks. It does not take much experience to recognize this problem. The solution is to increase air discharge rates immediately to provide a 2-3 mg/L DO in the aerator. A time clock may be necessary to keep the DO up. See Part I, Section 4, Aeration Basin, for a typical time clock setting.

When the system is operating well, it will generally have a dark brown aeration tank color and will be accompanied by an earthy odor. If the mixed liquor solids level becomes too low, the odor will either disappear or change to that of fresh grease or lard.

CLARIFIER

The operator should also observe the final effluent and the clarifier water surface to see how the process is working.

Final Effluent Appearance

If the effluent is clear—fine!

If the final effluent appears clear or is improving day by day, obviously the operator should continue to do what he has been doing.

But . . .

If not, something needs to be done.

However, if it appears turbid or contains noticeable solids, trouble may be just around the corner. Visual observations and control tests will help to show what needs to be done.

Final Clarifier Surface Appearance

Sludge Bulking: Operators who have experienced true classic sludge bulking find it all too easy to remember and identify. It will usually show up as a uniform sludge blanket that lies a few inches below the surface of the entire clarifier and may even cause the mixed liquor solids to pour out over the final effluent weirs. It may be due to shock loadings and inefficient aeration devices; however, classic sludge building usually is caused by improper operational control rather than by inadequate plant capacity.

How is sludge bulking controlled?

This type of bulking, which is practically always associated with young sludge, usually can be eliminated by reducing sludge wasting rates and changing return sludge rates. If a centrifuge is used to find RAS concentrations, the goal should be to adjust the return rate to equal the concentration found in the settlometer settling test after 2-3 hours of settling. This concentration can be found by multiplying the mixed liquor concentration by 1,000 and dividing by the volume settled after 2-3 hours. Adjust the return rate either up by 20 percent to cause the desired change and recheck after 24 hours. If this causes improvement, keep going in this direction. If not, move return in other direction. Sludge blanket in the clarifier should be watched for improvement too. Some sludge may still be lost in the effluent, but the goal is to bring the sludge quality back into a good range.

If the plant has the capability, contact stabilization might also be tried if the condition does not improve in 10-14 days.

For further information, see EPA Bulletins 330/9-74-001 a, b, c, d, and e and Operator Pocket Guide to Activated Sludge, Part II, listed in the References Section of this manual.

How does solids washout differ from sludge bulking?

Sludge Solids Washout: Excessive sludge washout over the final effluent weirs, when the upper surface of the sludge blanket is more than three feet below the clarifier water surface and when sludge settles properly in the laboratory tests, should not be confused with classic sludge bulking.

Solids washout is generally caused by hydraulic overloading, improper clarifier inlet port arrangements, or faulty final effluent weir locations or a combination of these.

Clumping: At times, large masses of sludge, possibly four inches (0.11 meter) in diameter, may be seen rising, then bursting, and finally spreading over the clarifier surface. This has sometimes been called "clumping." This may also indicate a need to scrape the sides of sloping clarifiers that do not have mechanical sludge removal.

Ashing: At other times, smaller sludge particles usually deep brown to gray in color, may rise and then spread over the tank surface. Some operators call this "ashing."

What happens when the sludge age is too old?

This problem occurs when sludge age is too old and it can usually be eliminated by increasing sludge wasting rates. Reducing air discharge rates to the minimum levels that will still maintain aerobic conditions in the aeration tanks may also be helpful.

What factors make straggler floc worse?

Straggler Floc: At times, small, almost transparent, very light fluffy, buoyant sludge particles (1/8 to 1/4 inch, 3-6 mm in diameter) may rise to the clarifier surface near the outlet weirs. This condition is usually worse in a shallow clarifier and may be especially noticeable at high return sludge flow rates. When this type of straggler floc is observed while the final effluent is otherwise exceptionally clear, and if it is present even during relatively low discharge periods, sludge age should be increased. Since this type of straggler floc usually occurs at relatively low mixed liquor solids concentrations and is usually worse during the early morning hours, it may be reduced by cutting back on sludge wasting rates 10-20 percent. This will increase sludge age. Return sludge and air discharge rates are controlled by results calculated from other control tests.

What is pin floc?

Pin Floc: Very small compact pin floc, usually less than 1/32 of an inch (0.8 mm) in diameter, may be observed suspended throughout moderately turbid final clarifier tank contents. This is a strong indication that sludge age is too high and the sludge has become overoxidized. This results from high return rates which cause the sludge to make too many passes through the aeration in a days time.

How does settlometer test confirm pin floc?

The settlometer test will confirm this if rapidly-settling, discrete sludge particles appear as individual "grains" or granular rather than clumping together. The sludge tends to accumulate rather than compact while forming a settlometer sludge blanket. In essence, granular sludge particles are falling through a turbid liquor rather than compacting and squeezing out a clear final effluent. When final clarifier characteristics are confirmed by the settlometer test, the sludge wasting rate should be increased while return sludge flow is adjusted to meet other control test demands.

RETURN ACTIVATED SLUDGE

The Return Activated Sludge (RAS) condition should be observed as it discharges into the aeration basin. A good RAS has a brown color, no offensive odor and good settling in the clarifier prior to pumping to the aeration tank.

What are the causes of a septic RAS?

A black and odorous sludge indicates that it has turned septic. Two possible causes are an excessively low rate of sludge return and not enough air supplied to the aeration basin. The first results in the sludge remaining in the clarifier too long and since it doesn't receive aeration, the sludge turns septic. The aeration basin should be checked for dissolved oxygen to see if low DO (less than 0.5) is the cause.

Is the pump operating correctly?

Sludge should be returning from the clarifier all the time unless it is necessary to shut it off to waste and then only for short periods of time (1-2 hours maximum). Material that blows into the clarifier may plug the suction line. This requires rodding out or blowing back with air or water.

Air lift pumps may not operate because the air line control valve vibrates shut. Valves should be checked each time the operator passes them. Handles and stems should be adjusted so they are tight and not knocked out of adjustment by bumping or vibration.

Is return sludge measured?

The meter or measuring device for return sludge should be read and a record kept on rate of return as well as total pumped each day.

Float type meters need to be checked daily to be sure nothing interferes with free operation of the float. Grease and sticks sometimes cause the float to stay in one place regardless of the flow, causing false readings.

Weirs that measure flow must be kept clean. Grease, weeds, trash, or thick sludge that collects on the weir edges will cause falsely high readings. The weirs should be checked and cleaned daily.

WASTE SLUDGE

Many small plants were never provided with a way to waste sludge nor a place to waste it to. Several suggestions are made in later portions of this manual to solve this problem.

Watch the wasting operation closely.

Other plants have methods of wasting either on a batch basis or continuously to an aerobic digester or to a holding tank. It is generally the best practice to waste only while the operator is on site to watch the operation. It is important to calculate the amount needed to be wasted and then to be sure not more than that amount is drawn out. When waste valves are left open overnight it is too easy to either waste too much or something plugs the line up and nothing is wasted.

Valves, meters, and pumps used in the wasting procedure should be checked at least every other hour when in use.

TOTAL SLUDGE LOSS

Oops!

Sometime, the operator may come to the plant and find that all or most of the solids have been washed out or wasted from the plant. The two most probable causes are hydraulic washout due to high flows or accidentally leaving a valve open.

Getting back in operation.

In either case, it will be necessary to start over and build new activated sludge. Several options are available:

Beg

1. Check with a neighboring activated sludge plant and see if some return sludge can be hauled in and dumped in the aeration basin. By using 5,000 gallons of return sludge at a concentration of 10,000 mg/L in an aeration tank holding 50,000 gallons, an instant MLSS of 1,000 mg/L would result.

Borrow

2. If the plant has an aerobic digester or holding tank, some of these solids could be transferred to the aeration tank. The bugs will not be as healthy but it will cause the process to come back faster than starting from "scratch."

Start from "scratch"

3. If it is necessary to start from nothing, it can be done by setting the return rate at maximum for 2-3 days and stopping wasting until the proper level of solids are built up. There will probably be foaming in the aeration tank and chemicals may be needed to keep it down. Also, a lawn sprinkler can be set up to spray over the surface of the tank.

   It may take 8-12 days to get back to normal. Return rates should be cut back at about 10 percent per day after the first 3 days. No wasting should be done until back to normal.

One other problem might result in sludge loss and this may be due to "toxic" or poison materials coming to the plant. Metal wastes, high organic content, or low or high pH are some of the possible causes. The sludge may lose its ability to settle and go out over the weirs.

The source must be found immediately and stopped. This requires the help of regulatory people usually.

Plant startup may be done in any of the above ways after the problem is found and corrected.

SECTION 3

TESTS AND INTERPRETATIONS

Listed below are sampling locations and tests that can be performed at a treatment plant. The list includes both those for operational control of the plant and are used to confirm conditions suspected in plant observation, and those that measure the efficiency of the treatment system and are used for reporting to the state regulatory agency. The tests indicated in **bold type** are those for which the procedure is described in Section 6.

Raw Wastewater	**Pretreat-ment**	**Aeration Tank**	**Clarifier**	**Chlorine Contact Chamber**
BOD_5 Suspended Solids (SS) pH Temperature Flow	None	Mixed Liquor Suspended Solids (MLSS) **Centrifuge** **Settlometer** **Settleability** **pH** Dissolved Oxygen (DO) Temperature	BOD_5 In/Out SS In/Out **pH In/Out** DO In/Out SS of Return Sludge Settleability Turbidity Out	**Residual Out** *BOD_5 Out SS Out Bacteriological Out (Fecal Coliform)
*Dechlorinate sample and reseed before running test.				

Those tests for which the procedure is not covered in Section 6 can be found in detail in the references listed at the end of Section 3.

Following is a discussion of the above tests and how they applied to treatment plant operation.

SETTLEABILITY

Purpose

This test is conducted daily to assist the operator in routine process control and identification of specific problems. It involves obtaining samples from the aeration tank and clarifier setting them at within five minutes of collection and allowing the samples to settle for a 30- or 60-minute period.

Interpretation

Well-Operating Plant

1. Mixed Liquor

   a. Sludge will be dense and will stay settled for at least one hour.

   b. Sludge reading should be about 50-70 percent at 5 minutes, 35-50 percent at 30 minutes, and 30-40 percent at 60 minutes. At about 30 percent at 1 hour, the foam in aeration tank begins to increase and turns white and color of tank contents gets lighter.

      NOTE: These figures are typical values and will vary from plant to plant.

   c. Supernatant should be clear.

2. Settling Tank Effluent

   a. Clear and solids free.

   b. Slight "dusting" of sludge on bottom of jar.

   c. Light solids suspended in a clear supernatant.

Poorly Operating Plant

1. Mixed Liquor

   a. Turbid settling vessel supernatant, black sludge, and odor (plant not getting enough air).

   b. Reddish color (overaeration).

   c. Solids in jar rise within an hour after settling (overaeration).

   d. Settleability after 5 minutes either above 80 percent or below 40 percent.

2. Settling Tank Effluent

   a. Turbid settling vessel supernatant (sludge is being mechanically torn apart in clarifier, or the sludge has gone septic due to remaining in clarifier too long. Sludge return line may be plugged).

Settlometer Tests

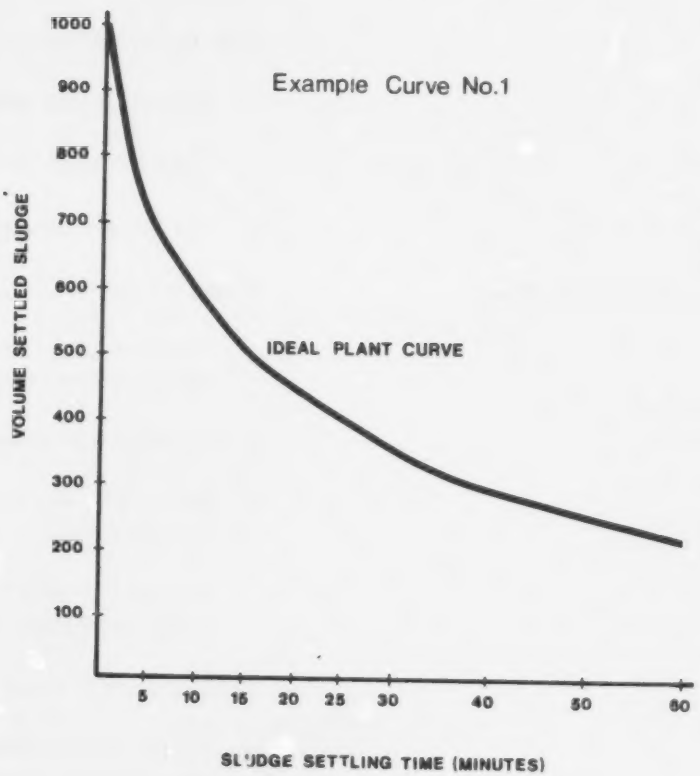
Purpose

This daily test is to observe sludge quality and to give the operator advance warning of the need to change process control. It is more informative than the previously mentioned settleability test.

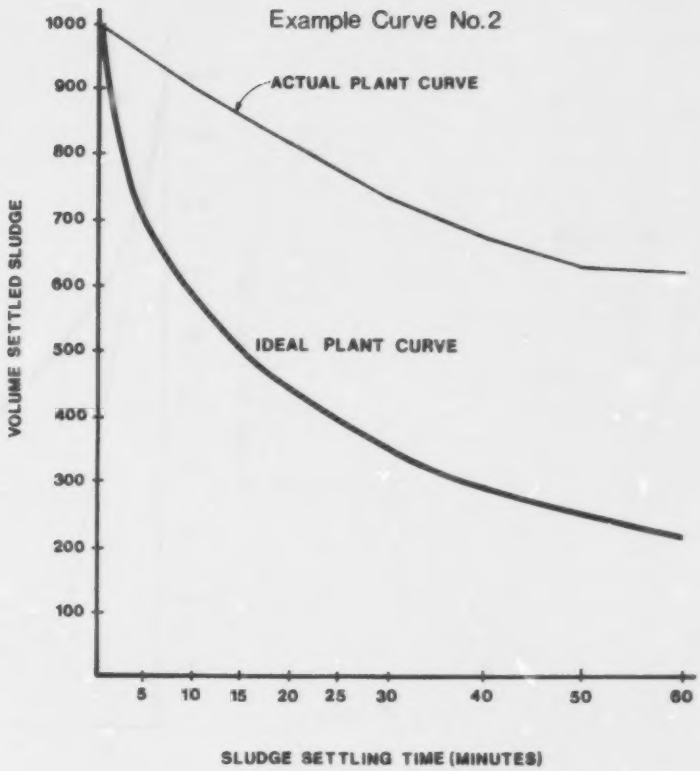
Interpretation

Plot the sludge settling data as shown in Example Curve No. 1. A blank form is included in Appendix D for copying. A typical plant that is operating properly should develop a similar curve. In each plant, a particular curve will occur when all phases of the plant are operating well; i.e., clear effluent, good settling in the clarifier, proper color. This curve, reflecting good operation of the plant, becomes the curve that the operator strives to maintain.

Ideal Curve



Young Sludge

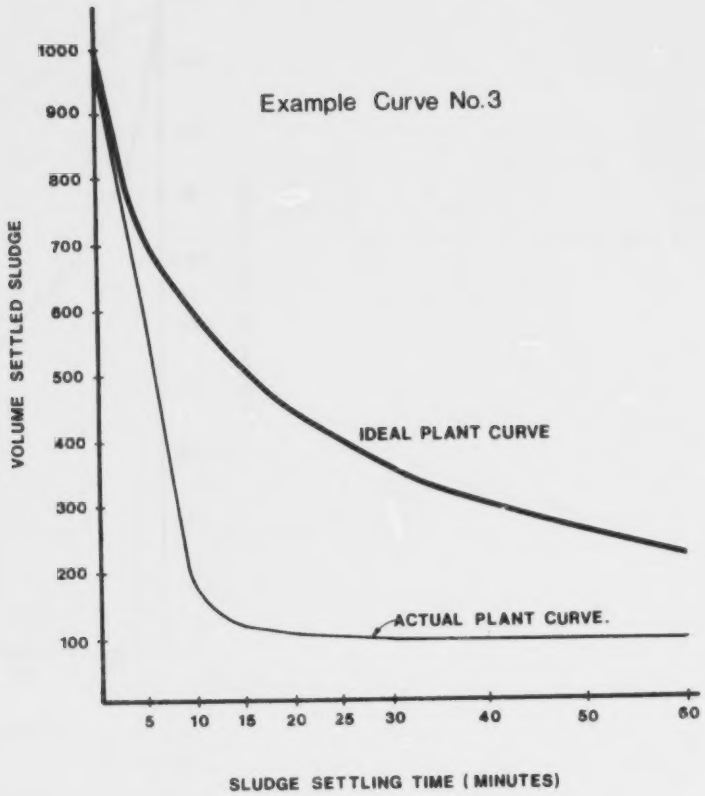


When the curve tends to rise from the ideal plant curve, as depicted in Example Curve No. 2 (usually accompanied by excessive white sudsy foam in the aeration basin), the sludge age is probably young and the return sludge rate from the clarifier should be adjusted. This is usually done in steps of 20 percent increase at one time. This also should be accomplished by decreasing the sludge wasting from the system and reducing the air into the aeration basin.

Possible causes of this condition are: too great or too fast a removal of sludge from the system or high organic load.

Old Sludge

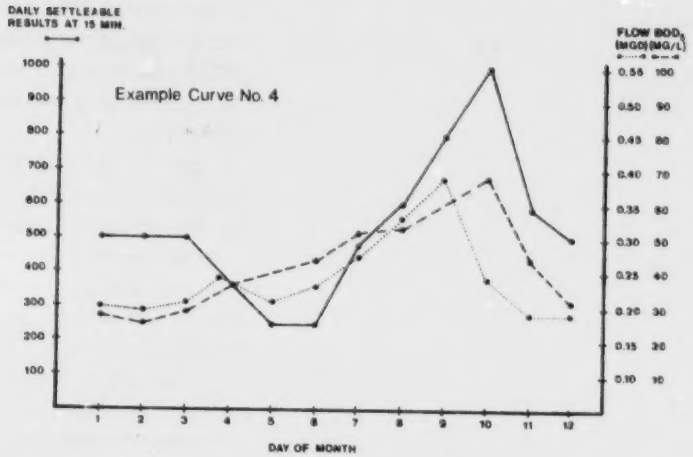
Example Curve No.3



When the resulting curve drops down from the ideal plant curve, as depicted in Example Curve No. 3 (usually accompanied by thick, scummy, dark tan foam), the sludge age is considered to be too old and the operator should begin to increase the sludge wasting rate. (See the topic on Observations: Aeration Tank, of Section 2 for information on sludge wasting.) Possible causes are: reduced organic loading, too high a return rate from the clarifier, long periods of overaeration, and retaining old sludge for long periods of time.

Graphing Lab Results

These day-to-day curves may be combined into a weekly or monthly graph as in Example Curve No. 4 (Appendix E contains a blank form for copying) along with additional data from flow, BOD_5, or just the operator's observation of the clearness of the supernatant. A scale could be made from 0-10 with "0" being a perfectly clear supernatant after 60 minutes of settling and 10 would represent a very murky liquid. This will give the operator a graphic view of the possible causes for changes in the process. The operator should then be able to know the limits of the plant, such as when a certain hydraulic surge or flow will cause solids loss and how long it takes to cause the loss, or at what MLSS level range does the clarifier perform well. It should also enable the operator to answer questions regarding the plant's ability to accept additional loads connected to the plant.



The settlometer test concept of operational control is explained in EPA bulletins available from the National Training and Operational Technology Center.

CENTRIFUGE FOR SUSPENDED SOLIDS

Purpose

This is a quick method of estimating the mixed liquor suspended solids concentration.

Interpretation of Results

If the suspended solids concentration is above or below the desired range, then the proper changes in the pumping rate of the waste and return sludge should be made. Part II, Section 2, gives ranges of mixed liquor suspended solids ranges for different types of treatment processes.

pH TEST

Purpose

This daily test is used to determine the acidity or alkalinity of the wastewater, both the raw waste and mixed liquor.

Interpretation

A "neutral" pH is 7. Below that, an acidic condition exists and above 7 alkaline conditions exist. The most favorable pH for a biological system is between 6.5 and 7.5, but the aeration basin may have a range of 5-8. Extreme changes in raw waste pH may indicate an industrial spill. If the pH does change abnormally, it can be corrected by adding certain chemicals. The state regulatory official or the operator's consulting engineer should be contacted for instructions.

pH change not related to industrial spills may be observed. A low pH following clarification may indicate that the sludge is remaining too long in the clarifier. A low pH after chlorination may indicate overchlorination which results in the formation of hydrochloric acid. A chlorine residual test should be made to confirm any suspicion of overchlorination.

Low pH in the mixed liquor in plants with high sludge age may be caused by nitrification depleting alkalinity, particularly if the alkalinity of the raw waste is low (less than 100). Sodium bicarbonate may be added without causing problems. Check with your consultant or regulatory personnel.

RESIDUAL CHLORINE TEST

Purpose

This daily test is used to determine if the chlorinator is operating at a level to kill the bacteria before discharge of the wastewater.

Interpretation

The chlorine residual will typically be between 0.5 and 1.0 milligrams per liter (mg/L), but may vary from 0.2-2.0 mg/L. Bacteriological tests should be made to determine what residual is needed to provide the necessary coliform level called for in the NPDES permit.

OTHER TESTS AND MEASUREMENTS

In some cases, the operator may need to make more in-depth tests to tell how well the plant is working. Possibly these tests will be handled by an outside contractor. If not, three publications that will provide detailed information on how to perform these and other tests are listed under References at the end of this section.

Flow

Flow may be recorded in gallons per day (gpd), million gallons per day (mgd), liters per day, and cubic meters per day. Flow information is critical to the operation of the plant. The operator should have a flow recorder that is capable of giving the flow at a particular instant and the total flow over a definite time period. The flow is sometimes read from an indicator and may be recorded on a strip chart or circular recorder which continuously plots the flow through the treatment plant. This knowledge is helpful in finding at what part of the day the treatment plant is receiving the high and sometimes troublesome flows. If the meter has a totalizer, the reading should be written down daily and the reading for the previous day subtracted from it to get the total flow in 24 hours. By adding these figures and dividing by days in the month, the average flow is found.

Another method to find average daily flow for the month is as follows:

$$\text{Avg. Daily Flow} = \frac{\text{Total Flow, Beginning - Ending Reading}}{\text{Number of Days in Recording Period}}$$

$$= \quad \text{gpd (Liters or Cubic Meters per Day)}$$

Daily records of the meter reading should be kept. It is important to take the reading at the same time each day. These daily records are important in determining the cause of changes in treatment plant efficiency and can be used as shown in the settlometer test. A blank form is included in Appendix F for copying and using.

For more detailed information on different methods of flow measurement, consult the Sacramento Manual listed at the end of this section.

BOD_5 (5-Day Biochemical Oxygen Demand)

This test is a measurement of the amount of oxygen required in a 5-day period by the microorganisms in consuming the organic material in the wastewater. BOD_5 is used to present historic information on the efficiency of the treatment system in reducing the oxygen demand of the wastewater. The test is usually run on both the influent and effluent. Long-term trends can be observed by studying BOD_5 results.

Suspended Solids (SS)

This test measures the amount of solids that are either floating on the surface or in suspension with the wastewater SS tests are usually run on the influent and effluent. When used to take the suspended solids of the aeration tank, it is referred to as the Mixed Liquor Suspended Solids (MLSS).

Temperature

The temperature of the aeration tank contents should be taken daily by reading the thermometer while it is submersed in the water. Temperature affects the efficiency of the biological process. Proper recording of the temperature aids the operator in detecting long-term trends. Rapid downward changes during rain storms may also indicate infiltration.

Mixed Liquor Suspended Solids (MLSS)

The test for MLSS measures the amount of solids in the aeration basin which, in turn, gives an indication of the amount of bugs there are. The activated sludge process is controlled by maintaining certain levels of MLSS. Part II, Section 2, gives typical values of MLSS levels.

Dissolved Oxygen (DO)

Dissolved oxygen can be read directly by using a meter or by the Winkler titration test. It is important to maintain proper DO levels in the aeration basin for an activated sludge process to work. Possible suppliers of DO meters are Yellow Springs Instrument Co., Yellow Springs, Ohio 45387; or Weston and Stack, 446 Lancaster Avenue, Malvern, Pennsylvania 19355.

Bacteriological

The success of disinfection is determined by bacteriological tests on the effluent of the chlorine contact chamber. This is usually done by determining the amount of fecal coliform bacteria in the wastewater. Note that samples collected for these tests must contain sodium thiosulfate to destroy residual chlorine at time of sampling.

References

1. ***Simplified Laboratory Procedures for Wastewater Examination***. 1976 (Second Edition) by the Water Pollution Control Federation, 2626 Pennsylvania Avenue, Washington, D.C. 20037.

2. ***Operation of Wastewater Treatment Plants***. By Ken Kerri of the Sacramento State College Department of Civil Engineering (commonly known as the Sacramento Manual).

3. *Standard Methods for the Examination of Water and Wastewater*. Published by American Public Health Association, American Water Works Association and Water Pollution Control Federation.

4. *Methods for Chemical Analysis of Water and Wastes*. Environmental Protection Agency, National Research Center, Analytical Quality Control Laboratory, Cincinnati, Ohio 45268.

5. *Self-Monitoring Procedures for NPDES Permits* (Student Reference Manuals). EPA National Training Center, Cincinnati, Ohio 45268.

SECTION 4

OPERATIONAL PROCEDURES

PRETREATMENT

Pretreatment facilities, the comminutor, bar screen, and/or grit chamber operate without any daily adjustment provided they are maintained according to the information given in the sections on Plant Checklist and Observations and according to manufacturer's recommendations.

All walkways in the pretreatment as well as other areas should be kept clean and free of grease.

AERATION BASIN

Conventional and Extended Aeration Activated Sludge

How is the correct amount of oxygen maintained?

One of the keys to proper activated sludge operation is maintaining the correct Dissolved Oxygen (DO) concentration throughout the aeration basin. Air can be added by the two methods discussed in Part II—Section 3, Diffusers and Surface Aerators. Two items are beneficial in insuring that the aerators supply the correct amount of oxygen. These are a timer and a method for measuring DO. The amount of oxygen that the treatment system needs varies throughout the day due to the changing flow into the p'ant. A blower supplying air to diffusers or a surface aerator may be connected to a timer so that air can be regulated as needed. The DO measurements are used to verify the settings on the timer . A possible operating scheme for a municipality or residential area is as follows:

How can DO be varied?

7 a.m. – 9 p.m.:	Blower or Aerator On All the Time
9 p.m. – 2 a.m.:	On 15 Minutes, Off 10 Minutes
2 a.m. – 7 a.m.:	On 10 Minutes, Off 10 Minutes

A DO reading should be taken at 8 a.m.

If above 4.0 mg/L, cut back on the air at night.
If below 1.0 mg/L, increase aeration time at night.

Besides the normal daily variations in flow, other major effects on the operation of the aeration basin are:

How is the effect of hydraulic overload reduced?

1. Hydraulic overload (flow is greater than that for for which the plant is designed) which may be due to a growth in the service area of the treatment plant or to infiltration into the sewer lines during storms and high groundwater levels. The effect can be reduced by installing a surge basin ahead of the treatment plant to equalize the flow throughout the day. A representative of the state regulatory agency or the consulting engineer should be consulted for assistance before building a surge basin.

What should the operator do if it is suspected that someone is dumping a strong waste into the sewer?

2. Organic overload usually occurs during the 7 a.m. to 9 p.m. period when the treatment plant is already receiving its heaviest load and someone dumps a strong waste into the sewer. If this is suspected, the operator should make a survey of places such as schools and other institutions to see if food waste, dishwashing water, and/or shower drainage is entering the sewer at the same time. If so, the problem should be explained to institution officials and alternatives suggested. These might include scheduling dumping during low flow period or installing a holding tank to allow waste discharge to be spread over longer periods.

Where do grease and fat problems originate?

3. Slug loads, such as cooking fat or oil, can cause problems because the bugs may not be able to use it as food fast enough. It can also be unsightly and odorous. Restaurants and large institutions should be checked as possible sources of fat. Motor oil may also come to the plant from service station sumps that are illegally connected to the sewer system.

4. The amount of activated sludge returned to the aeration basin is important to having good treatment. Return sludge pumps should be properly maintained and the settlometer test (see Part i—Section 3 and 6) should be run daily to tell if the sludge is settling properly.

5. Sludge should be periodically wasted to maintain the proper balance in the system. The settlometer test and amount of solids in the system should be used to gain information on when to waste.

Contact Stabilization

The operational procedures for contact stabilization are similar to those for the conventional and extended aeration activated sludge processes except that the sludge is returned to a reaeration (stabilization) basin prior to passing to the aeration (contact) basin. (See the Basics, Section 2.)

For the reaeration basin, complete mixing and dissolved oxygen must be maintained. A DO level between 1.0 and 4.0 mg/L is an average range.

Why is the reaeration basin run at higher solids levels?

The settlometer centrifuge tests should be used to control the solids levels in the contact and reaeration basins. The reaeration basin should be run at higher solids levels (3-6 times) than that in the contact basin. This allows the operator to increase the rate of return solids to the contact basin during the daytime period when the load or strength of the wastewater is greatest. Prior to leaving at the end of the day, the operator should then reduce the return flow to the contact tank.

Because the solids in the reaeration basin are not affected directly by the flow into the plant, only by the rate of return, the danger of losing solids during high flows is much less. The contact tank removes the food by settling, the sludge is returned to the reaeration tank where the bugs have more time to use the food.

All visual observations regarding the aeration basin in Section 2 also apply to the contact and reaeration basins, however, it is normal to have more thick foam on the reaeration basin because of the normally higher solids content.

CLARIFIER AND RETURN ACTIVATED SLUDGE

The key to good clarifier performance is maintaining calm conditions so that the solids will settle to the bottom. Two things that might upset these calm conditions are:

What happens when the clarifier is disturbed by high flows?

1. Too high a sludge return rate (over 100 percent of influent rate) tends to disturb the sludge blanket at the bottom of the clarifier and causes solids to rise and flow over the effluent weir. The rate should be set to maintain the concentration found after 1.5 to 3.0 hours settling in the settlometer when the plant is producing clear effluent.

2. If a plant is operating at or near its hydraulic capacity, the wastewater isn't detained as long in the clarifier and the efficiency of the settling is affected. Continuous operation of the scum skimmer could provide enough additional turbulence to further hinder settling. If such is the case, the operator should try operating the skimmer just often enough to keep from losing scum in the effluent.

What is the effect of too slow a sludge return?

The return activated sludge should be pumped either continuously at a steady rate or at regular intervals. Care must be taken not to pump the sludge so fast that it becomes too thin or disturbs the clarifier. Neither should it be so slow that the sludge blanket builds up.

In a rectangular clarifier, the operator might experience sludge building up in the corners and turning septic. If such is the case, the operator may have to scrape the corners daily with a long handled scraper so that the sludge will be picked up by the return sludge pump.

WASTING PROGRAM AND DIGESTION

All activated sludge plants build up excesss sludge and require periodic wasting. Control tests, such as the settlometer and MLSS solids, should be used to determine when and how much to waste. All wasting should be done in small amounts, not more than 20 percent of the total sludge volume per day until the desired level is reached. Larger waste amounts may upset the balance maintained by the biological system.

What is sludge age?

Sludge age, which is controlled by the sludge wasting rate, indicates the approximate number of days that an average activated sludge "bug" remains in the system before being wasted. Too much sludge wasting will reduce sludge age by increasing the relative amount of newly developed floc in the system. If wasting rates are too low, it will increase the number of days the sludge is kept in the system and will increase the relative amount of older sludge.

How should changes in sludge wasting be made?

What test should be made to give information on sludge wasting?

Sludge wasting rates should be reduced gradually on a day-to-day basis to correct the problem of excessive white foam. Best results are usually found by reducing the wasting rate approximately 20 percent of return flow on each successive day until the mixed liquor is back to normal. When things are correct, the operator should keep the lowered wasting rate for about three more days to allow the sludge to stabilize. The operator should plot volume settled sludge and sludge settling time on a graph as shown in Section 3—Settlometer, which will alert him or her to future control adjustments that may be needed. Wasting usually should not be stopped completely. When sludge is settling very poorly and sludge is bulking at the same time white foam is forming, it may be corrected by reducing the air feed rate to 1.0 mg/L or less DO.

How is sludge wasted in plants without provisions for such?

Following is a method for wasting sludge from plants without an aerobic digester or holding tank: Shut the return sludge pump off but still allow the mixed liquor to flow to the clarifier. This action concentrates the solids in the bottom of the clarifier. The volume of sludge should then

be estimated by the depth of the sludge layer. A portable pump or an adapter on the return sludge line could be used to transfer the sludge to a tank truck for hauling to an approved site designated by the regulatory agency. In some cases, a drying bed might be constructed on site. Assistance should be obtained from a consultant and the regulatory agency.

As suggested above, this method of sludge wasting is possible if the plant is equipped with an air lift return sludge pump. A plugged tee can be placed in the eductor pipe as shown in Part III–Section 1, Case Histories. When it is time to waste, the valve on the line leading to the aeration basin is closed and a line for the waste sludge is connected at the tee.

How does the operator determine the amount of sludge to waste?

Listed below are formulas that allow the operator to calculate how much to waste each day.

1. $$\% \text{ Sludge Vol.} = \frac{\text{Actual Depth of Sludge in Feet}}{\text{Depth From Bottom of Tank to Water Level in Feet}} \times (100)$$

2. $$\text{Maximum Amount of Sludge to Waste Per Day} = \frac{(\text{Actual Depth of Sludge in Feet}) \times 2}{10}$$

3. After the desired amount of sludge is pumped out, the return pumps are turned on and normal operation is resumed. This operation should be done when flows are low and should not take over two hours.

Plants With Aerobic Sludge Digestion

As with the aeration basin, the key to digester operation is maintaining a proper dissolved oxygen concentration, in this case around 1 mg/L.

Other important items in operation are:

1. To allow room for added sludge to the digester, the aeration is turned off, and the solids are allowed to settle (usually takes one to two hours). Part of the supernatant is then pumped to the aeration basin and mixed with the wastewater being treated.

2. Solids levels that will still allow good settling should be maintained in the digester. At high concentrations (possibly above 10,000 to 20,000 mg/L) the solids do not separate from the liquid. Therefore,

while the aeration devices are turned off, enough sludge should be removed to maintain a proper solids level.

Disposal of the digested sludge should be on land or drying beds as approved by the state regulatory agency.

Plants Without Aerobic Sludge Digestion

Package treatment plants without sludge digestion have to obtain other methods to handle sludge. If the plant is not designed for wasting, a septic tank pumper may be used to pump the sludge out.

Disposal of the sludge must be at an approved site. This might be a sludge stabilization lagoon, a drying bed or land disposal. If a nearby treatment plant has the capacity, arrangements might be made with that operator to handle the sludge.

What advantage does a temporary storage tank for sludge offer?

Many plants find it difficult to get a septic tank hauler to pump a small amount of sludge at frequent intervals. A solution would be for the operator to obtain a 5,000-gallon (19 cubic meter) tank to store the sludge. Enough air would have to be provided to maintain aerobic conditions and prevent odors. Then, at less frequent intervals, the septic tank hauler would empty the storage tank.

DISINFECTION

Disinfection of the wastewater, usually by chlorine, must be a continuous process. To determine the level at which to set the chlorinator, chlorine residual tests should be run as described in Part I—Section 6, Laboratory Procedures.

The following items are important to effective and safe operation of the chlorinating facility:

How does the operator verify one hour detention?

1. A detention time, generally one hour, is necessary to allow the chlorine to contact and kill the bacteria. One hour detention and effective mixing can be verified by adding dye at the point of chlorine discharge and check the time required for the majority of the dye to appear in the effluent. It may be necessary to install baffles as shown in the drawing of the chlorine contact basin in Part II—Section 3.

2. Replacement chlorine containers should be connected so that gas supply will not be interrupted. The amount of chlorine used should be recorded daily in order to know when to switch containers.

How does the operator check for chlorine leaks?

3. The chlorine piping should be checked daily for leaks. Chlorine will cause an ammonia water soaked cloth to give off a white cloud of ammonia chloride.

CHEMICAL ADDITIONS

Why is it disadvantageous to use chemicals?

Chemicals have been used occasionally for temporary relief of problems in biological treatment systems. Alum, ferric chloride, and polymers are sometimes added to the clarifier to assist in settling. When chemicals such as alum are used, they will increase the volume of return sludge and may reduce the pH of the sludge.

Chlorine is used to reduce the odors from septic influent wastewaters. Care must be taken not to chlorinate the influent to a level that will kill the bugs in the aeration basin. A proper dosage, to be added over a 24-hour period, is 1/2 pound chlorine for every 10,000 gallons of wastewater (6 mg/L).

Bicarbonate of soda may be used to raise pH in the aeration basin. A guideline for the amount to add is to maintain a minimum of 25 mg/L bicarbonate alkalinity. The procedure for running the alkalinity test is in ***Standard Methods*** and ***Simplified Laboratory Procedures*** cited in the Bibliography in Appendix A.

The pH will vary some during normal wastewater treatment. A sudden rise or drop may indicate an industrial discharge and it is often too late for any pH control to save the bugs. If a plant has persistent problems with pH, a state regulatory official should be contacted for technical assistance in regard to pH control. Efforts should be made to eliminate the cause at its source through the use of city ordinances prohibiting the dumping of strong acidic or basic wastes.

Are enzymes a good buy?

There has been much discussion over the use of enzymes in the aeration basin. In specific instances, enzyme addition may be helpful to treatment, but only after laboratory testing to determine which type would be effective. Due to the high cost of enzymes and their controversial nature, it is suggested that before making a decision concerning enzymes the operator read the article by James C. Young, entitled "The Use of Enzymes and Biocatalytic Additives for Wastewater Treatment Processes." (***Deeds and Data***, May 1976, Water Pollution Control Federation.)

SECTION 5

FINAL PLANT SURVEY

Before leaving for the day, one final inspection should be made around the plant. The following questions may help in seeing that the operator has left the plant in a condition that it will operate well until the next time it is attended.

1. Are there any pieces of equipment that are running poorly that may have to be checked before the next scheduled day of operation (hot bearings, loose belts, etc.)?

2. Are return sludge rates set at correct level?

3. Are flowmeters clean and operating?

4. Are inlet gates set properly in case of high flows before the next plant visit.

5. Are air flow rates set properly?

6. If some processes are time-clock controlled, are time clocks set?

7. If remote alarms are used to warn someone about power or equipment failures, are these set to turn on?

8. Is equipment stored and locked so as to prevent vandalism?

9. Are outside lights on or set to come on?

10. Is plant secured to prevent vandalism?

SECTION 6

LABORATORY PROCEDURES

Following are the laboratory procedures for the tests that are discussed in detail in Section 3.

SETTLEABILITY

Purpose

This test is conducted daily to assist the operator in routine process control and identification of specific problems, using one of the following:

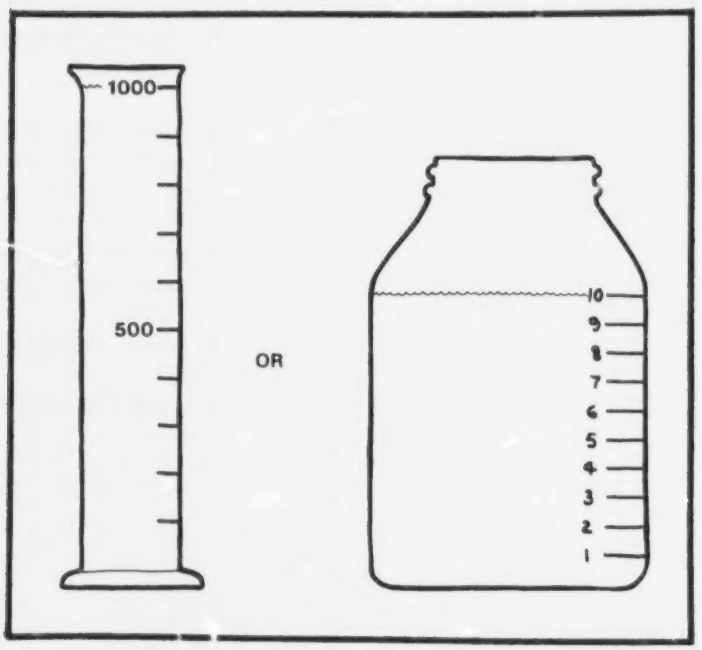
Equipment

1. Quart or liter jars (clear glass) marked with a scale from 9-10.

2. Graduated glass cylinders (1,000 milliliter capacity).

OR

3. 2-liter beaker.



Procedure

1 Fill the container with mixed liquor (liquid from aeration tank).

It should be filled to the upper mark on the scale.

NOTE: A more informative test on the mixed liquor is the Settlometer test described later.

2. Let container sit for 60 minutes.

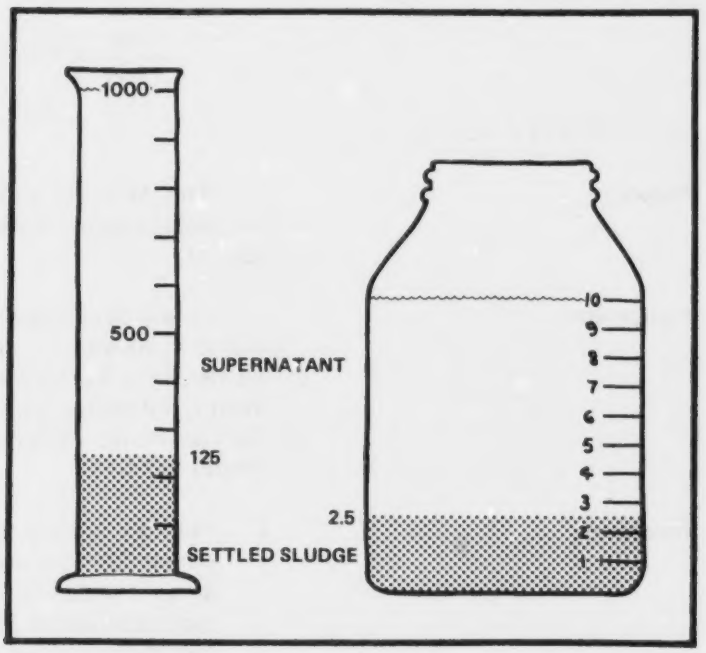
3. At 5, 30, and 60 minutes note:

   a. Mixed Liquor

      (1) Scale reading at top of settled sludge.

      (2) Density of sludge (thick or light).

      (3) Clarity of supernatant (clear or cloudy).



Example Calculations

Sludge Scale Reading

1 Glass Jar:

(scale reading) x (10) = **% sludge volume**

Example:

(2.5)(10) = 25% sludge volume

2. 1,000 ml Graduated Cylinder:

$$\frac{\text{(scale reading)}}{10} = \textbf{\% sludge volume}$$

Example:

$$\frac{250}{10} = 25\% \text{ sludge volume}$$

3. 2-Liter Beaker Marked From 0-1,000:

$$\frac{\text{(scale reading)}}{1{,}000} \times 100 = \textbf{\% sludge volume}$$

Example:

$$\frac{250}{1{,}000} \times 100 = 25\% \text{ sludge volume}$$

SETTLOMETER TESTS

Purpose

This daily test is to observe sludge quality and to give the operator advance warning of the need to change process control.

Equipment

One glass container equivalent to the five-inch (13 cm) diameter, six-inch (15 cm) depth, two-liter Mallory "Settlometer" that is graduated in hundreds is needed. The equipment is obtainable from laboratory supply houses such as SGA Scientific, 2375 Pratt Boulevard, Elkgrove Village, Illinois 60007.

Procedure

1. Fill the container to the upper mark on the scale with a sample from the aeration tank with the least possible amount of additional aeration or disturbance. For contact stabilization, tests should be run on both the contact and reaeration tank.

2. Stir contents gently and then dampen immediately with a wide paddle before starting timer.

3. Read and record the volume occupied by the settled sludge every five minutes for the first 30 minutes and at 10-minute intervals for the second 30 minutes of the one-hour test.

   NOTE: During the first five minutes, the operator should observe how the sludge particles come together while forming a blanket on the bottom.

   Does the sludge compact slowly and uniformly while squeezing clear liquid from the sludge mass? This is an indication of good sludge.

   Do tightly knotted sludge particles fall down through a turbid supernatant? This indicates an old sludge in poor condition.

   How much and what type of floc (sludge particles) if any, remains in the supernatant above the main sludge mass? Note types on daily log.

4. At 60 minutes the sludge characteristics should again be noted as this will show what the sludge will do in the clarifier. A sludge that starts rising again by the 60-minute time may be overoxidized.

   NOTE: A properly oxidized sludge will not start rising to the surface until two to four hours after the test was started.

CENTRIFUGE FOR SUSPENDED SOLIDS

Purpose

This is a quick method of estimating the mixed liquor suspended solids concentration.

Equipment

1. Laboratory centrifuge with speed control.
2. Graduated centrifuge tubes, standard API calibrated 0-100 perce. t, 0-15 ml, or 0-30 ml.

Procedure

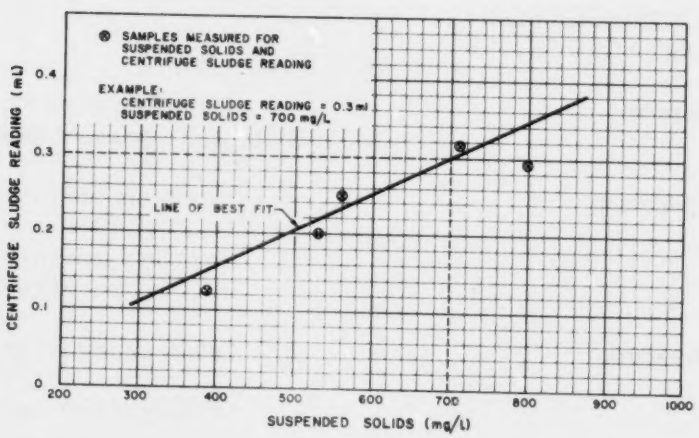
1. Collect sample in regular sampling can.
2. Mix sample well and fill each centrifuge tube to the top line with sample and place in centrifuge holders. If the machine will handle four tubes, use two for MLSS and two for RAS.

3. If centrifuge is hand powered, crank at a fast speed while counting slowly to 60. Count and crank at the same speed for all tests. The most accurate ones are motor driven. Use maximum speed for 15 minutes if motorized. In either case, it is extremely important to perform each step exactly the same every time.

4. Remove tubes and read the amount of suspended solids concentrated in the bottom of each one. This reading will be in percent or tenths of a milliliter. Average the values if two or more tubes are used.

5. Refer to conversion graph to determine suspended solids in mg/L.

   NOTE: Graph must be developed for each plant. This can be done by taking a sample from the aeration tank and measuring suspended solids by the regular Gooch Crucible Method or membrane filter and centrifuging a portion of the same sample to obtain the centrifuge sludge reading in ml of sludge at the bottom of the tube. Keep records on other samples at different solids concentrations to obtain the points on the graph, as shown in the following example. Draw a line of best fit through the points. With each major change in weather or sludge condition, the points should be checked because the influent characteristics and conditions in the aeration tank change (approximately every two to three months).



pH TEST

Purpose

This daily test is used to determine the acidity or alkalinity of the wastewater, both the raw waste and mixed liquor.

NOTE: The following test uses color comparison and will not be allowed by U.S. EPA for NPDES reporting. The procedure is included for use for process control as a handy tool. A pH meter, when purchased, should come with complete instructions for its use, therefore, no instructions are presented here.

Equipment

1. pH comparator
2. Brom thymol blue indicator
3. Eye dropper with a 1 ml mark on glass tube

Procedure

1. Obtain a fresh sample of raw waste.
2. Fill the tubes with a portion of the sample.
3. To one tube add the amount of indicator recommended on the pH disc.
4. Place tube with indicator in the opening behind the clear glass.
5. Place tube without indicator in the opening behind the colored disc.
6. Compare colors by rotating the disc. Read the pH of the indicator having the color closest to the sample color.

   NOTE: Some comparators have standard color solution vials instead of the disc. If so, change vials until color matches.

7. Wash and dry sample tubes.
8. Repeat procedure using supernatant from a sample of mixed liquor. This test should be run **within 10 minutes of collection time**.

   NOTE: When using an electric pH meter, a sample of mixed liquor can be run directly.

RESIDUAL CHLORINE TEST

Purpose

This daily test is used to determine if the chlorinator is operating at a level to kill the coliform bacteria before discharge of the wastewater.

NOTE: As with pH, color comparison will not be allowed for NPDES reporting. A replacement test is the starch iodide method found in the references at the end of this section. Kits such as the Model CN 65, which make the test easier, are availabile from Hach Chemical Co. or Bausch and Lomb Mini-Spectronic 20.

Equipment

1. Chlorine comparator (same as for pH but change the disc for chlorine)
2. A fresh (within six months) supply of orthotolidine reagent
3. Eye dropper with a 1 ml mark on glass tube

Procedure

1. Fill tubes with liquid taken from outlet of chlorine contact chamber, hold tube in hand for few minutes if liquid is not room temperature.
2. Place one tube in the opening behind the colored disc.
3. To the other tube add 1 ml of orthotolidine and place in the opening behind the clear glass.

SECTION 7

TROUBLESHOOTING

Troubleshooting begins by knowing the system. The operator needs to know:

1. What each part of the system is supposed to do.
2. How each process or piece of equipment operates normally.
3. How to recognize abnormal conditions.
4. What alternatives are available when trouble develops.

Briefly, to recognize when something is bad, the operator must know how it works when no trouble exists.

The purpose of this section is to present a ready and quick operator's reference to process problems and their solutions.

The table is arranged in columns as explained below:

Condition: The information in this column shows what has been indicated or observed by the operator.

Possible Cause: This shows the most likely cause of the indicated upset.

Solutions: The operator should arrange the suggested solutions in the order that he wants to try them and proceed from the easiest to the most difficult.

Reference: The numbers appearing in this column show where in the manual the operator can find additional information.

TROUBLESHOOTING

Condition	Possible Cause	Solution	References
Controls			
1. Pump fails to start	1. Overload relays tripped; starter coil damaged; HOA switch off; blown fuse; breaker off; alternator damaged.	1. Inspect; see "Motors," call electrician.	
2. Overloads trip	2. High amperage draw.	2. See "Motors."	
3. Starters chatter	3. Starter contacts burned; dirty contacts in alternator.	3. Clean, inspect or replace contacts.	
Pumps			
1. Unusual noise	1. Plugged impeller or suction; reciprocating pump pumping water instead of sludge (knocking noise).	1. Clean intake screen; remove pump housing and unclog impeller; turn off pump and check clarifier sludge blanket; too fast a pumping can suck a hole in the sludge blanket.	1. I-4 Clarifier & Return Activated Sludge I-3, Pumping
2. Vibration	2. Plugged pump priming line; see 1 above.	2. Remove and unplug line; check impeller for debris.	
3. Reduced pumping rate	3. Broken impeller; worn wear rings; see 1 above.	3. Disassemble, replace impeller; measure wear rings.	3. II-3, Pumping
Mechanical Seals			
1. Clogged filter	1. Innerseal leaking; bad motor bearings and vibration causing seal failure.	1. Repair bearings and seal(s).	
Motors			
1. Noise and/or vibration	1. Damaged, broken fan vanes.	1. Inspect and replace, if necessary.	
2. Run hot	2. Excessive bearing grease; wrong type of grease; overloaded; lack of grease.	2. See manufacturer's recommendations to verify correct amount and type of grease.	
3. High amperage	3. Drive motor too light for head requirements; too low discharge pressure; plugged impeller; damaged bearings; power imbalance; high or low voltage condition; misalignment.	3. Match equipment to load. Clean and repair impeller as necessary.	
Pretreatment			
1. Septic conditions upstream of bar screen	1. Infrequent cleaning causes organic material to settle out upstream. Comminutor not functioning properly or debris present which the equipment cannot remove.	1. Clean screen and flush sewer. Divert flow. Shut unit off and remove blockage.	1. I-2, Pretreatment
2. Odors around bar screen	2. Collected screenings not disposed frequently enough.	2. Remove screenings and bury with 6-12 inches (15-30 cm) earth cover.	
3. Leakage under drum of comminutor	3. Rubber seal worn or not seated.	3. Inspect, adjust or replace.	
4. Organics settling out in grit chamber	4. Flow too slow.	4. Reduce number of channels used during low flow. Introduce air into chamber to keep organics suspended.	4. III-1, Equipment Modifications

TROUBLESHOOTING

Condition	Possible Cause	Solution	References
Biological Treatment			
1. Turbid clarifier supernatant (effluent)	1. Return rate out of balance.	1. Adjust sludge return rate to match 1.5-3 hour settling concentration.	1. I-2 and 4, Clarifier
2. Black MLSS, septic odor and turbid supernatant	2. Not enough air; possibly localized septic pockets due to incomplete mixing.	2. Increase air supply. Check and clean diffusers.	2. I-2 and 4, Aeration Tank
3. Black MLSS and turbid supernatant	3. Abnormal pH; possibly due to industrial wastes.	3. Check pH. Add acid or sodium bicarbonate if pH is low. See state regulatory official for instructions.	3. I-3 and 6, pH
4. Reddish MLSS and return sludge	4. Overaeration; check DO to verify.	4. Reduce air to aeration tank.	4. I-4, Aeration Tank I-3, DO
5. Light brown aeration tank liquid and thinner solids	5. Insufficient sludge return.	5. Increase rate of sludge return to aeration tank.	5. I-2, Aeration Tank I-4, Clarifier and Return Activated Sludge
6. Clumps of black solids on clarifier and odorous	6. Solids remaining too long in clarifier and septic conditions occurring; sludge return line possibly plugged. Sides of hopper-type clarifier not scraped frequently enough.	6. Check sludge return lines for proper operation and increase sludge return rate.	6. I-2 and 4, Clarifier III-1, Equipment Modifications
7. Black aeration tank contents	7. Septic conditions.	7. Increase aeration.	
8. Excessive foaming	8. Too much activated sludge solids wasted at one time; insufficient air during high "storm" flows; plant recovering from overload or septic conditions; overaeration.	8. Can be controlled until eliminated by using a water spray. Solution is generally to stop wasting until solids are back up to normal.	8. I-2 and 4, Aeration Tank III-1, Equipment Modifications
9. Activated sludge bulking (activated sludge not settling in clarifier)	9. Too low solids level in system; strong stale septic sewage received after a storm following a long dry spell; poor grease trap cleaning (restaurant wastes); alkaline wastes from a laundry.	9. Check solids level with settling test. Increase sludge wasting. Increase air rate if test shows less than 0.5 milligrams per liter (ppm) dissolved oxygen near the surface of the settling tank. Hold approximately 1.0 mg/L.	9. I-2 and 4, Clarifier I-3 and 6, Settleability and Settlometer

Note: ***For more information, see "Operators Pocket Guide to Activated Sludge—Part II: Process Control and Troubleshooting." Available from Stevens, Thompson & Runyan, Inc., 5505 S.E. Milwaukie Avenue, Portland, Oregon 97202. Price: $1.00.***

SECTION 8

PLANT CHECKLIST

Following is a sample operation and maintenance schedule for a package plant. Although it is not a complete list of everything the operator should be observing, it will serve as a guide for setting up a schedule for his or her own plant. The schedule will help the operator organize work in a step-by-step fashion and it will also help relief operators or new personnel who are not familiar with the plant. For the design engineer, a checklist should be developed for the plant and included in the operation and maintenance manual.

The blank form in Appendix C may be used as a guide.

Most of the items are visual observations or maintenance needs that take little time if performed according to schedule. With regular attendance, the operator will develop ways to combine some of the duties. In many package plants that are looked after regularly by a conscientious operator, the scheduled items can be accomplished in one to two hours a day, allowing the balance of the time for lab and other duties.

Operational and Preventive Maintenance	Frequency						
	Daily	Wk.	Mo.	3 Mo.	6 Mo.	Yearly	As Necessary
Inlet and Outlet Facilities							
1. Clean weirs, weir troughs and weir boxes.	X						
2. Flush influent sewer, if possible, using water from fire hydrant or street cleaning water tank truck		X					
Pretreatment							
1. Remove and dispose of rags and accumulations from comminutor and screens.	X						
2. Observe flow and cutting action of comminutor. Plugging may occur if rags are not cut up.	X						
3. Check for rock or metal objects in comminutor channel.	X						
4. Sharpen comminutor blades when cutting edge is worn 1/8th of an inch (0.3 cm).							X
5. Grease comminutor, if called for in manufacturer's instructions.	X						
6. Check oil level of comminutor.		X					
7. Observe air flow in grit chamber and unclog any ineffective diffusers. Remove rags from diffusers daily.	X						
8. Remove scum from grit chamber.							X
9. Wash down grit chamber.	X						
10. Check grit pump packing for leakage, (20-30 drops per minute is normal).	X						
11. Inspect grit collection system.		X					
12. Remove and dispose of grit collection.							X
13. Wash down entire grit collection system.							X

(Continued)

Operational and Preventive Maintenance	Frequency						
	Daily	Wk.	Mo.	3 Mo.	6 Mo.	Yearly	As Necessary
Aeration Basin							
1. Visually check aeration system for even air distribution, no dead spots.	X						
2. Raise and clean rags from diffusers.		X					
3. Check oil level in mechanical aerator gear cases.		X					
4. Check oil level in blower gear cases.	X						
5. Check for air leaks around base and fittings of blower.	X						
6. Check blower belts for wear and tension.		X					
7. Check blower motor and bearings for excessive heat.	X						
8. Check aeration system for unusual noises or vibration.	X						
Clarifier							
1. Scrape sides and sloping bottom of clarifier.							X
2. Check to see if sludge collection arm is turning.	X						
3. Remove any floating material on top of clarifier.	X						
4. Verify that scum skimmer is depositing all scum in hopper.	X						
5. Pump scum box and hose down.	X						
6. Scrub launders and weirs with brush.		X					

(Continued)

Operational and Preventive Maintenance	Frequency						
	Daily	Wk.	Mo.	3 Mo.	6 Mo.	Yearly	As Necessary
Pumps and Motors							
1. Check for blockages in RAS return pump.	X						
2. Check pumps for clogging or near clogging condition.	X						
3. Clean screen at intake of suction piping of pump.							X
4. Lubricate pump bearings.							X
5. Check pump bearings temperature.	X						
6. Drain pump lubricants, wash out oil wells and bearings with kerosene.				X			
7. Check pump bearings for wear.				X			
8. Check alignment of pump and motor flange, with straight edge.					X		
9. Check motors for heating.	X						
10. Replace pump packing.							X
11. Check pump shaft sleeves.			X				
12. Replace pump shaft sleeves							X
13. Examine pump wearing rings (manufacturer should specify what is excessive).						X	
14. Clean water seal piping.						X	
15. Inspect foot valves and check valves.					X		
Operational Controls							
1. Observe odor, color, and foam of aeration tank.	X						
2. Perform necessary operational and control tests (settleability test, pH, chlorine residual, etc.).	X						
3. Perform tests as required by NPDES permit and regulatory agency.							X

PART 2

BASICS

SECTION 1

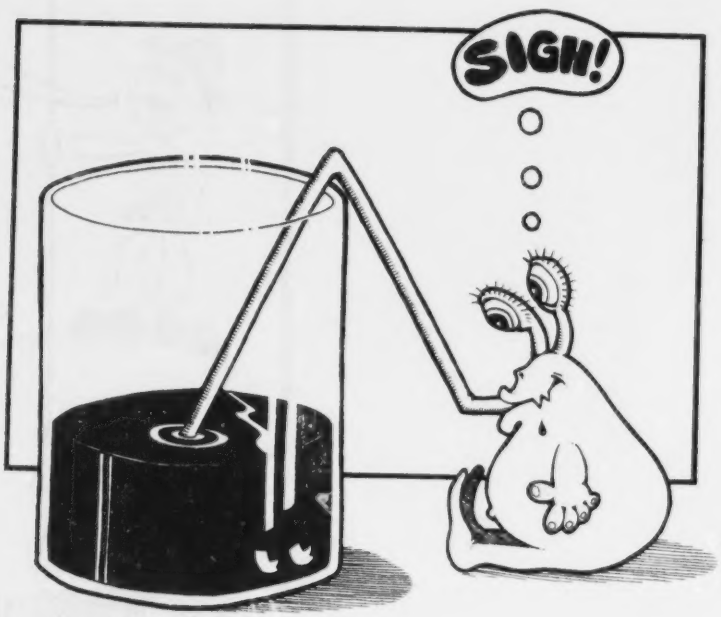
BASIC PRINCIPLES OF WASTEWATER TREATMENT

Wastewater contains both **suspended** and **dissolved** pollutants. In order to treat the wastewater, two methods are used to get rid of these pollutants. Part of the suspended pollutants are taken out with screens and settling, and the rest are biologically changed to a form that is more easily removed.

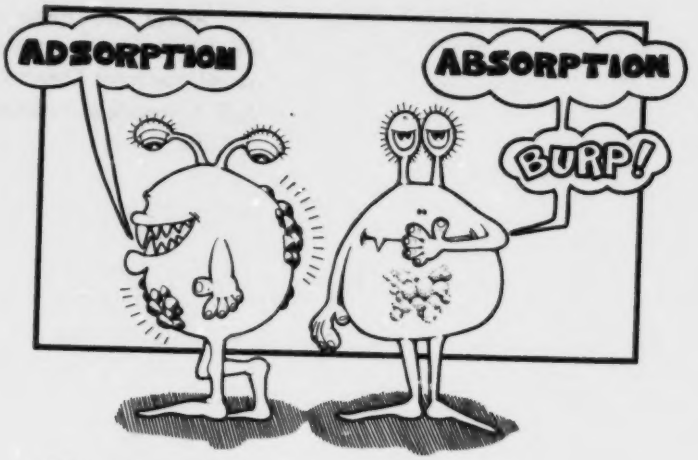
If only physical removal is used, objects removed are those that would float or settle under calm conditions. Physical treatment protects the river or lake from eyesores like floating bottles or rags that occasionally get washed into the sewer.

Smaller particles, if they are not removed, might cause the river or lake to become cloudy or murky. These particles may also require oxygen from the stream as they decompose. If there are many of these particles, the dissolved oxygen content of the stream, necessary for fish life, would be reduced.

The other type of pollutant in the wastewater, the dissolved one, must be changed in form before it can be removed. Fortunately, there is a character that will help us do this. It is the **microorganism**, or "bug," as it is sometimes called. The bug uses the dissolved organic material as food.

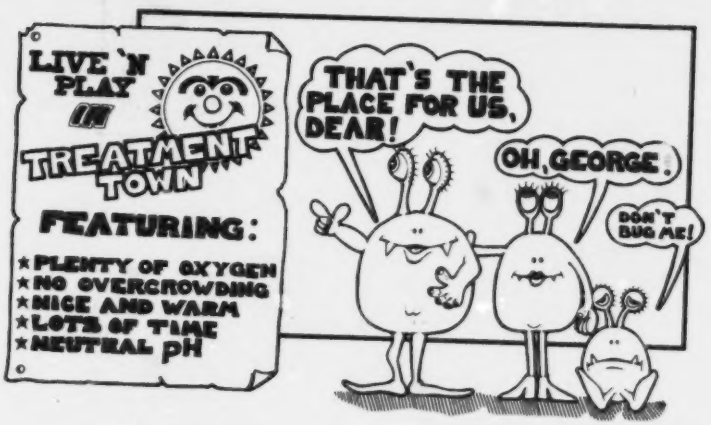


The bug can take up some of the suspended organic material also. Material may come into contact with the bug, attaching to the outside. This is called **adsorption**. Later, food is **absorbed** through its cell wall so that the food can be digested. Oxygen from air forced into the liquid is required for the bug to function and grow so that new bugs can be produced.



When the bug has taken in the pollutants in the wastewater, it can be removed by settling. Now the dissolved material has been converted to a form (called sludge) which can be removed by the physical means described earlier.

Just like you and I, the bugs need a healthy environment in which to live and grow: enough oxygen (1-2 milligrams per liter), the right number of bugs for the food coming in, a neutral pH, a warm temperature between 59 to 95 degrees Fahrenheit (15 to 35 degrees Celsius), and enough time to digest the food. If these conditions are maintained, and proper sludge wasting and return sludge flow procedures are followed, the bugs will reward us with a cleaner wastewater. Otherwise, conditions such as too much food for the number of bugs, high flows, lack of wasting, or too much air may prevent the production of a good clear effluent.



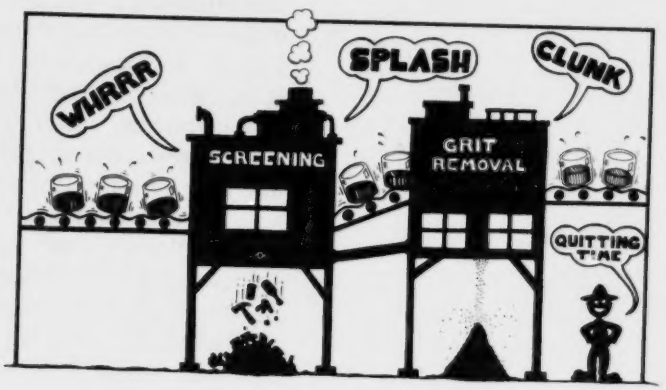
Note: For more detailed information, see "Operator's Pocket Guide to Activated Sludge—Part 1: The Basics." Available from Stevens, Thompson & Runyan, Inc., 5505 S.E. Milwaukie Avenue, Portland, Oregon 97202. Price: $1.00.

SECTION 2

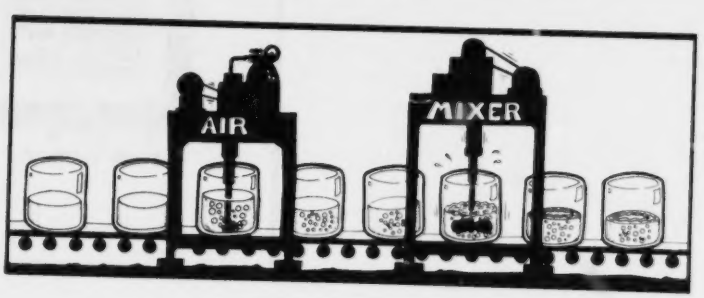
TYPES OF WASTEWATER TREATMENT PROCESSES

Conventional Activated Sludge

Conventional activated sludge is one type of process that makes use of bugs under **aerobic** conditions. Aerobic means in the presence of oxygen. After the wastewater has passed through the pretreatment process, screening, grit removal, and comminution, it enters the activated sludge system.



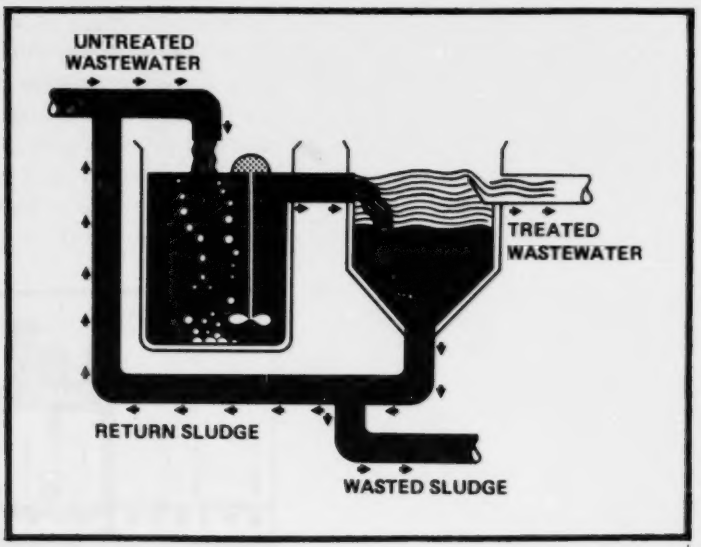
The first point of interest is the **aeration tank**. Here, the wastewater is detained long enough (four to eight hours) for the bugs to eat the **organics** in the wastewater. Organics are waste materials which come from animal or vegetable origins and can be eaten by the bugs. **Oxygen** and **mixing** are required for the bugs to come in contact and digest or metabolize the organics. The products are new bugs, carbon dioxide, ammonia, and water. A **Dissolved Oxygen (DO)** level between one to two mg/L should usually be maintained in the aeration tank for this to occur.



The process of the eating and digestion occurs in two steps. First, the particle sticks to the surface of the bug. This is called "**ad**sorption." Secondly, "**ab**sorption" occurs and consists of the organic material passing through the cell wall of the bug where it is digested.

The bugs tend to bunch together and form a floc which occurs throughout the aeration tank. This wastewater-bug mixture is called the **"mixed liquor"** and the concentration of bugs in the mixed liquor is defined as the **"Mixed Liquor Suspended Solids" (MLSS).** For a properly operating activated sludge system on ordinary municipal wastes, the MLSS concentration should be held at the level that gives the best effluent. If the MLSS concentration or sludge volume is too low, there would not be enough bugs to adequately treat the wastes. If the MLSS concentration or sludge volume is too high, the bugs will not all settle in the clarifier which follows the aeration tank. The mixed liquor should also have a musty odor and dark brown color.

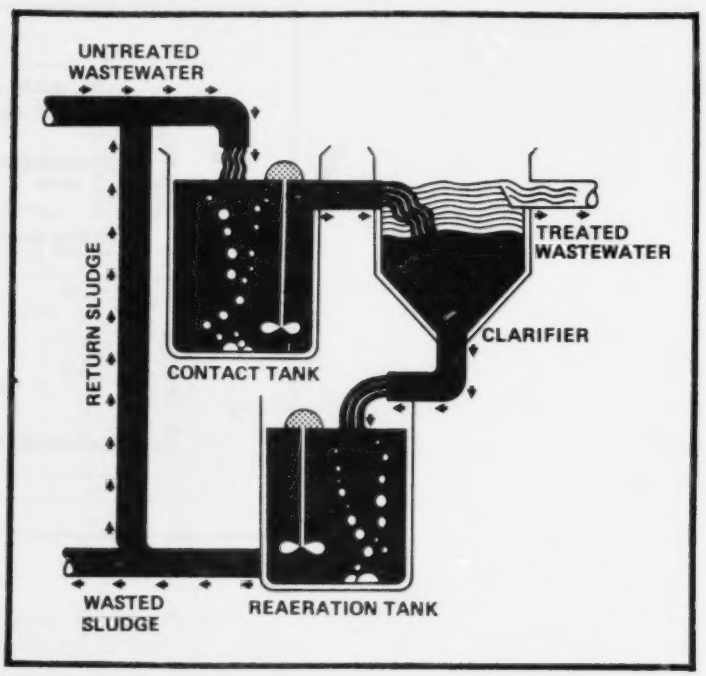
The **clarifier** performs the function of removing the bugs and any floating scum from the wastewater. The settled bugs form what is called activated sludge. The activated sludge is pumped back to the aeration tank to maintain the correct level of MLSS. With the bugs eating the food the wastewater contains, there is an increase in the population of the bugs. When this occurs, some of the activated sludge has to be **"wasted"** or not returned to the aeration tank.



This waste (or excess) sludge is usually pumped to a digester to stabilize it and then possibly to sludge drying beds for dewatering. With the bugs settled to form a sludge and the scum removed, the clarified wastewater flows on to another tank for disinfection.

Contact Stabilization

Contact stabilization is similar to conventional activated sludge except that the capture of the waste material and the digestion of that material by the bugs is done in different aeration tanks. The bug can "adsorb" the waste material on the cell wall in only fifteen to thirty minutes, but it takes several hours to "absorb" the material through the cell wall. In conventional activated sludge, adsorption and absorption are done in one tank, therefore, the wastewater has to remain there for a longer period. In both cases, the bugs flow to the clarifier to be separated from the wastewater, but in contact-stabilization the settled bugs still have to digest their food. Another aeration tank called a stabilization or reaeration tank is provided separately for this step. Here the bugs digest the food and then are returned hungry to the original aeration tank (contact tank) ready to eat more food.



The Mixed Liquor Suspended Solids (MLSS) concentration of the contact tank should be maintained around 1,500-2,000 mg/L. If the MLSS gets too high, the sludge

that the microorganisms form is disposed of or "wasted" as in conventional activated sludge.

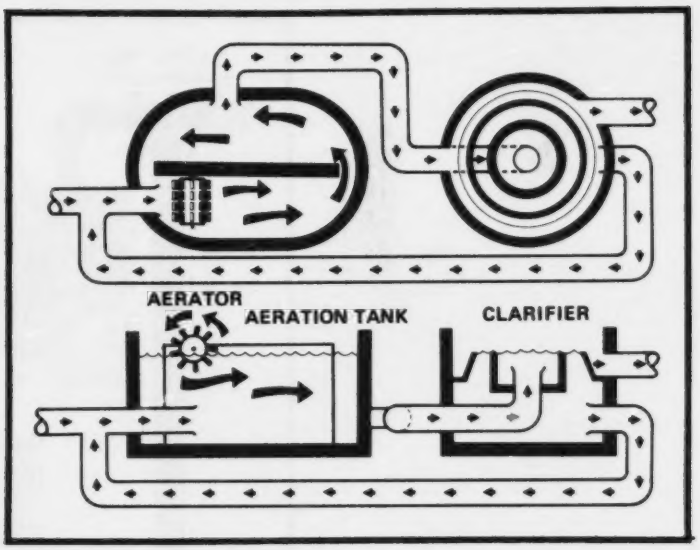
Extended Aeration

Extended aeration is similar to conventional activated sludge except that the bugs are retained in the aeration tank longer and do not get as much food. The bugs get less food because there is a high mixed liquor suspended solids concentration, 2,000-5,000 mg/L. In addition to the bugs consuming the incoming food, they, in turn, consume any stored food in the dead bugs. The new products are carbon dioxide, water, and a biologically inert residue.

Extended aeration does not produce as much waste sludge as other processes; however, wasting still may be necessary to maintain proper control of the process.

Oxidation Ditch

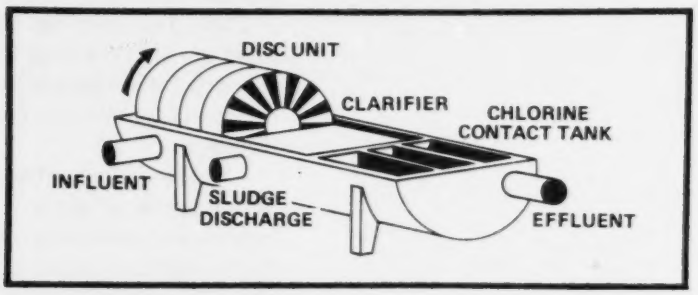
The oxidation ditch can be operated as either a conventional or extended aeration activated sludge treatment system. An oxidation ditch system consists of channels placed side by side, connected such that one continuous loop of the wastewater flow is obtained.



The wastewater is propelled and aerated by use of horizontal-shaft mechanical aerators placed in the channels. As with the other activated sludge systems, the wastewater then flows to the clarifier where the solids are settled and returned to the oxidation ditch to provide a fresh hungry group of bugs for the incoming wastewater.

RBC (Rotating Biological Contactor)

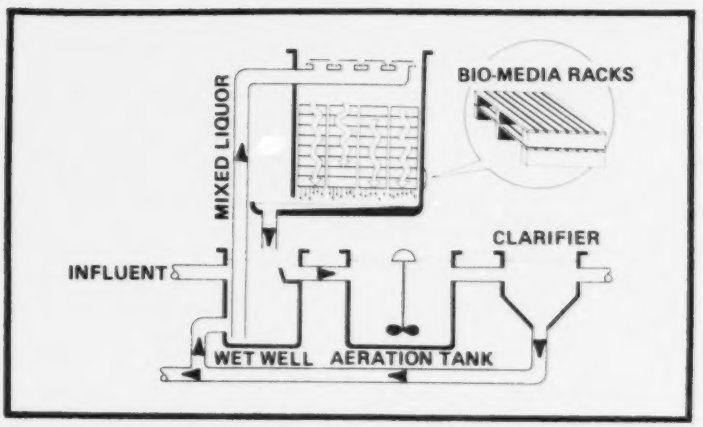
A bio-disc, or RBC (Rotating Biological Contactor as it is sometimes called, utilizes a biological slime of bugs which forms on a series of thin discs mounted side by side on a shaft. These discs are partially submerged by the wastewater and slowly rotate. The bugs obtain oxygen from the atmosphere at the exposed portion of the disc. The excess growth of bugs on the disc sloughs or breaks off and flows to the clarifier to be separated from the wastewater.



The principles of treatment are the same as in previously mentioned systems. The bugs adsorb and absorb the solids and soluble organics in the wastewater and digest the food with the aid of oxygen from the atmosphere.

ABF (Activated Bio-Filter)

The ABF makes use of both suspended microorganisms or bugs as in conventional activated sludge and a fixed microorganism growth as in bio-discs. The fixed growth occurs on wooden racks stacked on top of each other in a tank approximately 14 feet (4 meters) deep. The racks are made of wooden laths fixed to supporting rails. Oxygen is supplied to the wastewater and the bugs by the action of the water splashing between layers and moving in a film over the fixed growth.



The suspended bugs, as in conventional activated sludge, are mixed with the untreated wastewater, then are pumped up to the tank containing the wooden racks, then flow to an aerated tank before being separated in a clarifier. The sludge formed in the clarifier is returned to the untreated wastewater after the excess sludge is wasted.

Physical-Chemical

Besides the biological wastewater treatment processes mentioned previously, there also exists Physical-Chemical (P-Chem.) or advanced wastewater treatment plants. Instead of using the bugs to consume the pollutants, chemicals are added that react with the pollutants and allow them to be removed by physical means such as sedimentation and filtration.

Another form of advanced wastewater treatment makes use of activated carbon. The process of adsorption is used to remove the pollutants. Activated carbon can follow either the biological treatment systems mentioned previously or physical-chemical treatment to provide a higher degree of pollutant removal.

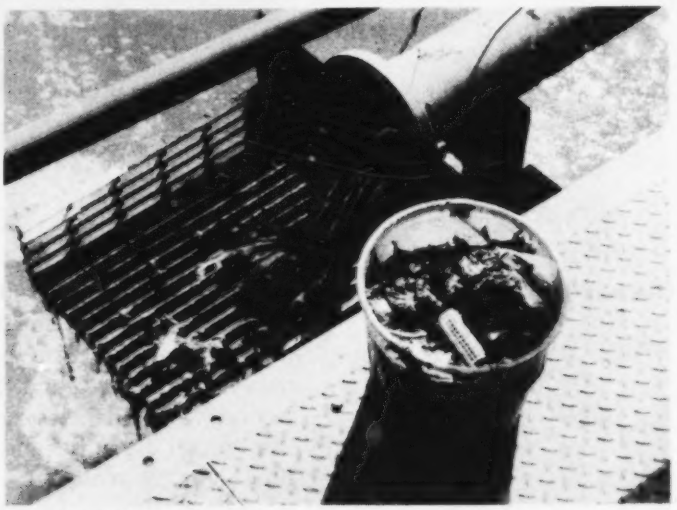
SECTION 3

DESCRIPTION OF UNIT PROCESS EQUIPMENT

Pretreatment

Screens

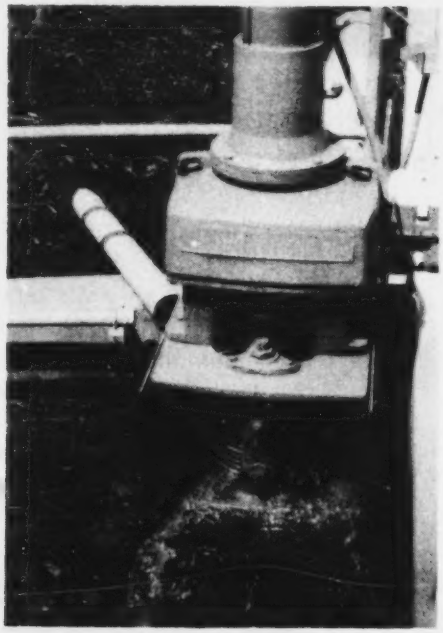
Screens are provided at the beginning of the treatment process to remove pieces of wood, rags, and other debris that get in the wastewater. These objects may damage the pumps or hinder in-plant flow. The screens usually consist of parallel bars placed vertically or at an angle in the channel through which the wastewater flows.



BAR SCREEN

Comminutor

Often following, and sometimes in parallel with a bar screen, is a comminutor. This device cuts up or shreds material as the wastewater flows through. It consists of a screen with cutting teeth moving through the openings. Solids are cut into fine particles that will not interfere with operation of the treatment plant.



COMMINUTOR

Grit Chamber

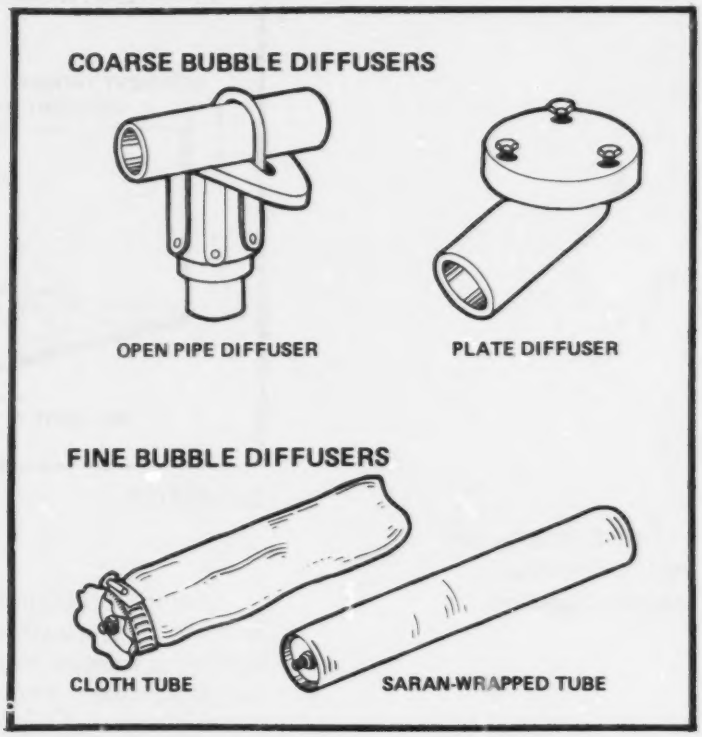
Inorganic material, such as eggshells and sand, is abrasive and damaging to equipment, and is not broken down in the treatment process. This material, called grit, will settle out if the velocity of the wastewater does not exceed one foot per second (fps) (0.3 meters per second). A grit chamber is a long trough that is designed such that the wastewater will flow at approximately one fps (0.3 mps) under average flow conditions. The settled grit is removed either by hand or mechanically, and is usually buried. In some grit chambers, air is added through diffusers to provide better separation of grit from other solids.

AERATION

Diffused Air

Diffused air systems are one method of supplying oxygen to the wastewater. The systems consist of a blower, air piping with mains, valves, meters, and other fittings used to carry air from the blowers to the air diffusers located at the bottom of the aeration tank. The diffusers are designed to produce either small or large bubbles. An equally important function of aeration devices is to maintain complete mixing throughout the aeration basin so that no stale or septic pockets exist.

Several types of diffusers are shown in the figure below.



AERATION DIFFUSERS

Surface Aerators

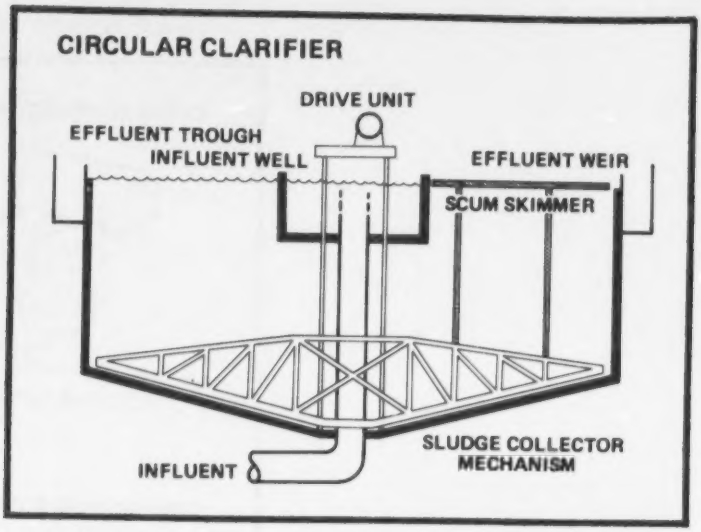
Surface aerators are also used to mix and supply oxygen to the wastewater. The aerator consists of a submerged impeller mounted vertically in the aeration tank. The motor, mounted overhead, turns the impeller vigorously allowing the wastewater to be aerated.

CLARIFICATION

Solids Separation

Sludge coming from the aerator must pass to a settling tank (clarifier) where the flow rate is slowed down to remove the bugs from the wastewater.

The shape of the clarifier may be either circular or rectangular, and is large enough to detain the wastewater for 1-1/2 to 2 hours. This detention time reduces the velocity and allows the solids time to settle. The settled solids (sludge) and floating solids (scum) are generally removed by mechanical collectors. The clarified wastewater passes over a long weir either at the end or around the basin. The weir should allow the wastewater to overflow at a velocity slow enough not to disturb the solids that have settled.



CLARIFIER

SLUDGE HANDLING AND DISPOSAL

Aerobic Digestion

Aerobic digestion is a method often used in package plants to prepare waste sludge for dewatering and disposal possibly as compost material or soil conditioner. The excess sludge from the treatment process is pumped to the digester where it is aerated for 20 days or longer in order to oxidize the remaining food. An extended aeration sludge requires 20 days, but a contact stabilization sludge requires longer. After aeration for the required time, the aerators are turned off and the sludge is allowed to settle. The liquid on top (supernatant) is returned to the aeration basin of the wastewater treatment plant. The sludge is pumped to dewatering facilities or land disposal. The whole process of settling and withdrawal may take from 1 to 4 hours. If it takes more than 8 hours to get 6 to 12 inches (15-30 cm) of supernatant, it is time to dispose of sludge.

Anaerobic Digestion

Anaerobic digestion is a continuous process of stabilizing waste sludge. Fresh sewage sludge is added continuously or at frequent intervals. The water separated from the sludge is normally removed as the sludge is added. Digested sludge is removed at less frequent intervals. The sludge is digested by bacteria, which use the organic material as food, and they give off the products carbon dioxide and methane gas.

Anaerobic digestion is generally not found on package treatment plants. If the operator is responsible for maintaining a digester, the following EPA publication should be obtained for information on the basics and operation.

(Operations Manual—Anaerobic Sludge Digestion, EPA Publication No. EPA 430/9-76-001.)

Sludge Drying Beds

Sludge drying beds are used to dewater the sludge coming from the digester. The surface of the bed is either sand with a gravel underdrain or the bed might be of asphalt.

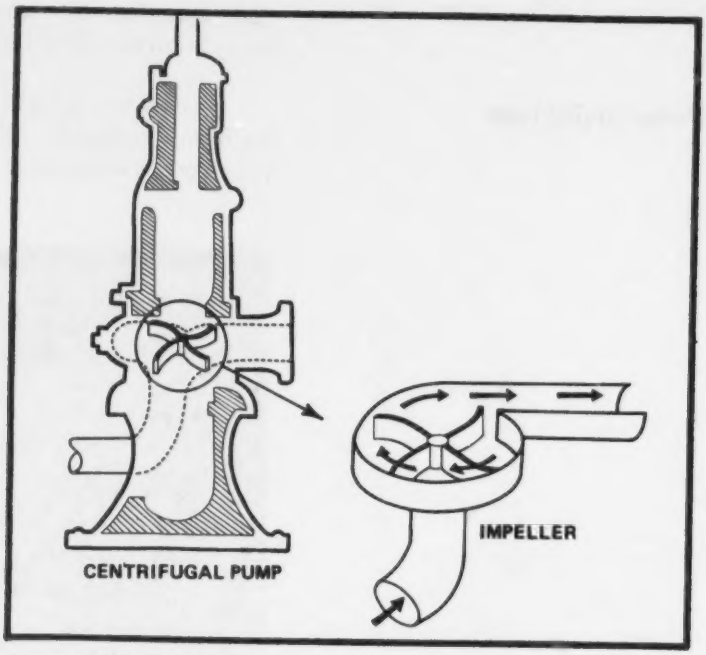
SLUDGE DRYING BED

Sludge may be placed on the surface 6 to 18 inches (15-46 cm) deep, depending on the climate. The drying is accomplished by evaporation and percolation of the moisture from the sludge. Removal of the dried sludge on the sand beds must be done by hand since heavy equipment will damage the underdrain. The underdrain is pumped back to the influent to the treatment plant. The dried sludge may be used as a soil conditioner and fertilizer. Some states have restrictions against placing the sludge on soil growing root crop vegetables; therefore, it is best to check with the regulatory agency first.

PUMPING

Centrifugal Pump

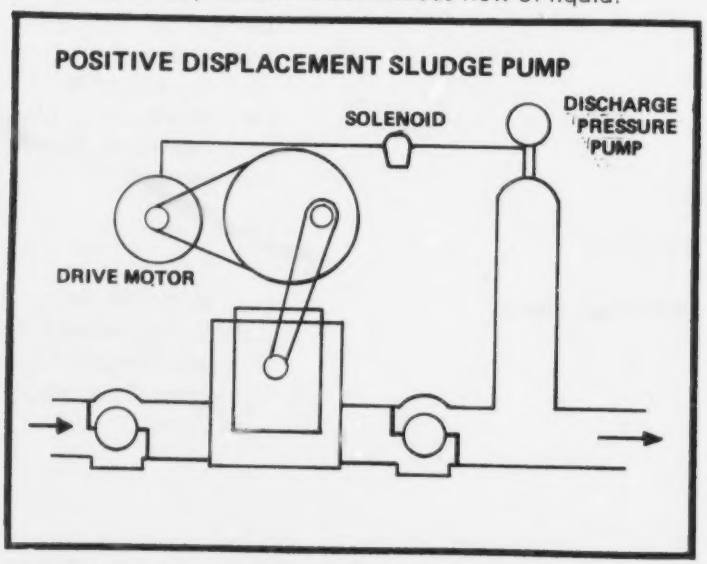
A centrifugal pump consists of an impeller rotating in a casing. The impeller is supported by a shaft and bearings. The liquid enters at the center of the impeller, is rotated by the vanes of the impeller, and thrown out the exit by centrifugal force.



CENTRIFUGAL PUMP

Reciprocating Pump

A reciprocating (positive displacement) pump is one that utilizes a piston to move sludge or water. When the piston retreats back up the cylinder, it allows a check valve to open so the fluid can flow in. On the following compression stroke, the inlet check valve closes and the outlet check valve opens, allowing the fluid to flow out. This action occurs repeatedly to allow a continuous flow of liquid.



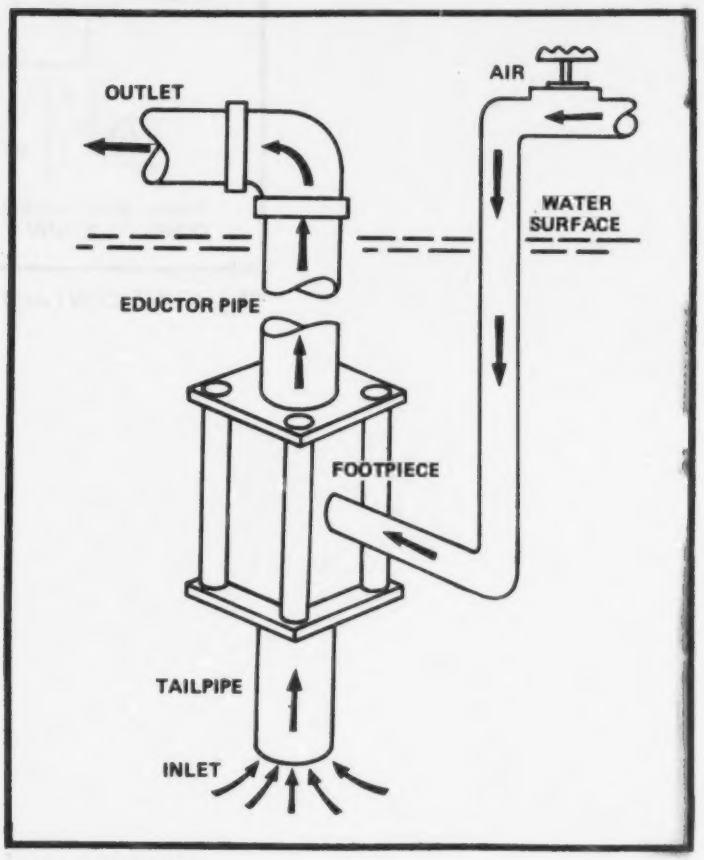
POSITIVE DISPLACEMENT PUMP

Air Lift Pump

An air lift pump is frequently used to pump sludge. It consists of a suction or eductor pipe placed vertically such that the suction end is in the sludge layer. Air enters the eductor pipe near the bottom. The rising bubbles cause a lower pressure inside the pipe causing the sludge to be lifted to the discharge point. Two possible causes of problems are:

1. The footpiece, or the point at which the air pipe joins the suction pipe, may become clogged so that there is not sufficient air to operate the air lift.

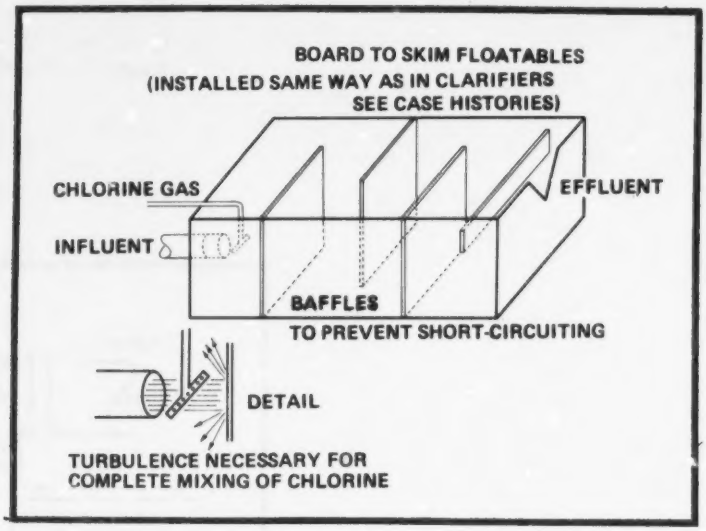
2. The entrance to the tail pipe (suction pipe) may become blocked from a large concentration of solids or objects too large to be pumped.



AIR LIFT PUMP

CHLORINATION

Chlorination is used at the last step in the treatment process to kill disease-causing organisms that exist in the wastewater. A basin, called the chlorine contact chamber, is provided to allow the chlorine sufficient time to be completely mixed and to "contact" the bacteria. A one-hour detention time is generally provided in order to kill the bacteria.



CHLORINE CONTACT TANK

SECTION 4

EFFECTS OF WEATHER

Environmental factors that affect the wastewater treatment process include temperature and precipitation. The wastewater temperature affects the activity of the microorganisms or bugs. During cold winter weather this reduced activity might lower the efficiency of the treatment system. Besides biological effects of temperature, the flocculation and sedimentation of the mixed liquor solids is not as effective at lower temperatures. Ice buildup will hinder or stop altogether the proper operation of mechanical parts such as sludge scraper mechanisms and aerators.

Precipitation over the area served by the treatment plant may cause the wastewater flow to increase due to the existence of combined sewers or due to infiltration into the sewer line. This is generally accompanied by a weaker wastewater in terms of Biochemical Oxygen Demand (BOD) due to the dilution effect of the stormwater. (See Glossary for explanation of BOD.) These occasions might cause the treatment system to be hydraulically overloaded. This results in a reduced time spent by the wastewater in the treatment system; thus, treatment efficiency is reduced.

Without plant modifications, there is not much the operator can do to offset the changes in treatment efficiency caused by temperature changes and high flows during storms. However, ice buildup can be controlled by frequent observation and removal during cold periods. For persistent cold weather problems, construction of a lightweight building over the aerator and clarifier may be more economical in the long run than fighting ice. Diffused air systems will supply sufficient heat inside the building to prevent ice from forming on the clarifier.

It normally will be necessary to vary the amount of sludge as seasons change. Because the bugs are not as active in winter at low temperatures, than in summer, the MLSS will need to be higher in the winter than in the summer.

PART 3

POTPOURRI

SECTION 1

CASE HISTORIES

In the course of writing this manual, several package plants were visited to observe and note innovative ideas by the operators and unusual operating conditions they experienced. Some of these are presented here as an example of things the operator can do at his own plant to improve performance or ease maintenance.

OPERATIONAL HINTS

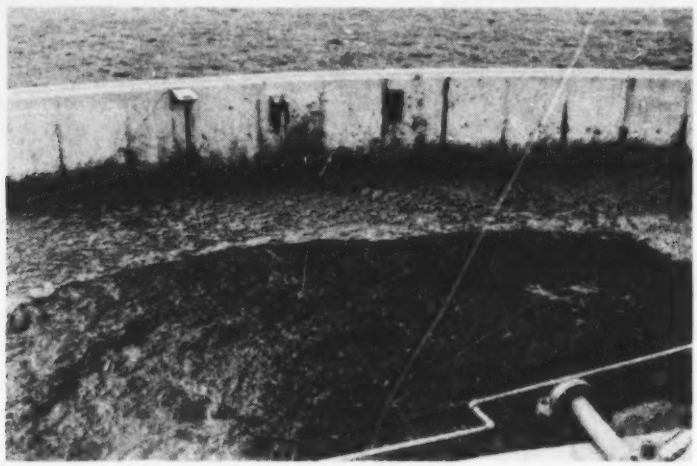
Tank Cleanliness

One operator of an activated sludge plant has a problem with scum in his plant due to a dog food processor discharging to the treatment system. This scum ends up in the aerobic digestion portion of the plant. When the sludge has been stabilized, the air supply is turned off and the solids are allowed to settle. The sludge solids are pumped to a tank truck for disposal. The floating scum should not be returned to the aeration tank with the supernatant; therefore, it is pumped out and disposed of by burying. To prevent odors due to the scum, the surfaces of all tanks containing the scum are hosed down daily.

Diffuser Clogging

Daily plant observation tells one operator when an air diffuser begins to clog. This is done by noting the surface area that is cleared of any foam or scum. When the diffuser begins to clog, this area will be reduced. As indicated in the

photo, the operator knows the diffuser is clogging because the scum is normally cleared across the whole width of the tank.



Aerator Time Clock Control

One operator of a plant serving a tourist facility has a varying flow based on the seasons. During the slow winter season, if the air diffusers ran full time, the contents of the aeration tank would be overaerated. To solve this problem, the operator connected the blower to a timer such that air would be supplied only an average of 15 minutes out of every hour.

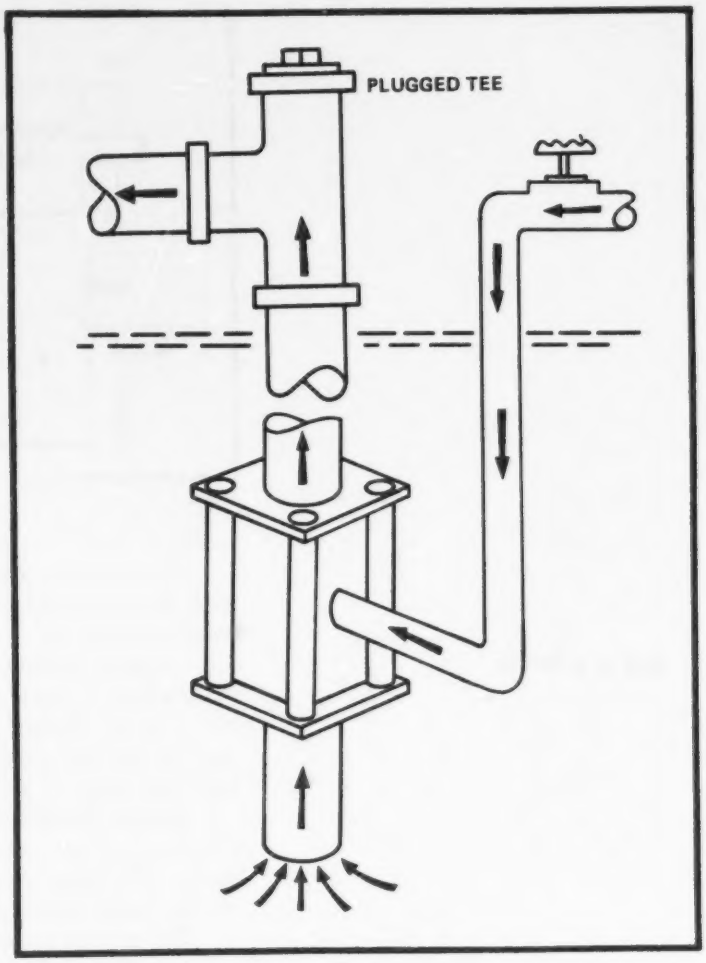
For normal operation of a plant, and especially one that is hydraulically overloaded, a possible solution to reducing a high solids level in the effluent is to operate the air lift scum skimmer in the clarifier only once a day. Any movement in the clarifier reduces the effectiveness of the unit and the skimmer movement tends to create an updraft in the flow, thus hindering settling.

EQUIPMENT MODIFICATIONS

Airlift Pump Plugging

Most of the clogging of air lift pumps occurs in the riser. This can be easily cleaned if there is a way to ram a small diameter pipe or rod down through the riser to the suction end. This can be done by replacing the ell at the top of the riser with a plugged tee as shown in the figure.

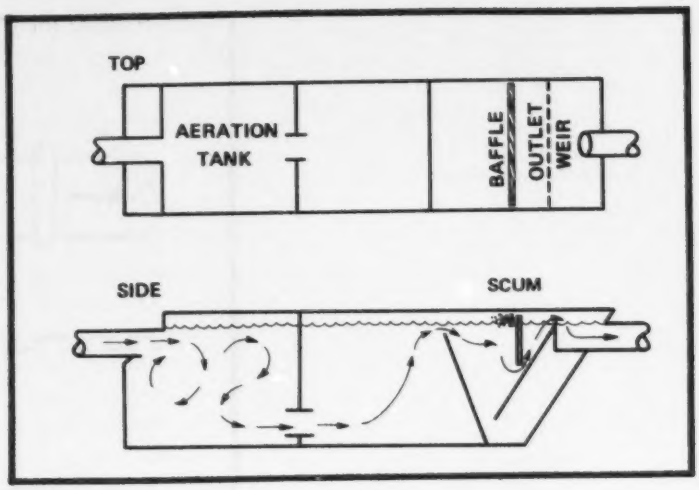
The plug can be removed after turning off the pump and the rod can be inserted to unclog the riser.



Another beneficial use of the plugged tee is that it provides a place for the operator to connect a line when it becomes necessary to waste sludge. When less flow is needed, due to fluctuating seasonal loads, a second smaller air lift might be installed.

Scum Baffle Installation

If a rectangular clarifier is not provided with a scum baffle, one can be constructed out of wood. Cut a 1 x 10 or 1 x 12 inch board long enough to wedge in the clarifier just prior to the overflow weir as shown in the drawing.



The wooden strip extends above and below the water level 10-12 inches (25-30 cm) in order to block any floating particles or scum.

Use of a Screen

Another method of preventing leaves and floating objects from flowing to the chlorine contact basin and then out with the effluent is a screen basket that may be hung on the clarifier discharge. A suitable wire mesh would be that found in rabbit hutches.

Similar baskets may be placed at the inlets to the aeration basin or clarifier, depending on the design of the package plant. The basket could contain a smaller one within it with window screen mesh to catch even smaller floatables.

Sometimes treatment plants are placed in areas where sticks and leaves from nearby trees create a major problem on the surface of the package plant. If this is the case, small treatment plants may be easily covered with a screen.

Air Regulation

Some treatment plants are not provided with a means to regulate the air to the aeration tank. To reduce the amount of air needed in these cases, one individual suggested putting a tap on the air line and having it "wasted" just below the water surface. The submerged discharge will eliminate the noise due to air being bled off, but at the same time will not affect the dissolved oxygen when air is being wasted to prevent high DO levels.

Odors in Grit Channels

Treatment plants are designed sometimes for larger flows than they receive initially. The lower flow may result in organics settling out in the grit chamber with the inorganics. This leads to odor problems. A solution to this is to tap the air supply line to the diffusers and have an air discharge in the grit chamber. The air outlets should be located approximately two to three feet (1/2 to 1 meter) apart

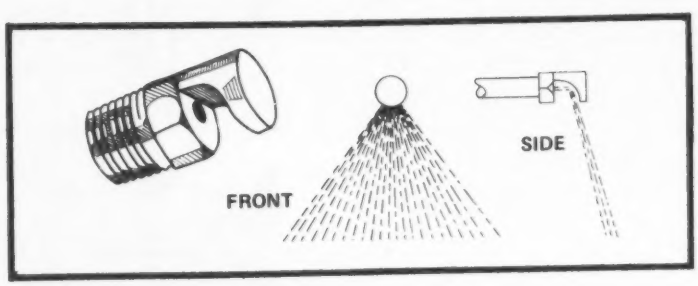
at the bottom of the channel with the air projected across the channel. A rolling action should be created that keeps the organics suspended but still allows the inorganics (grit) to settle.

Sludge Settling in Aeration Tanks

Rectangular aeration basins sometimes contain dead spots in the corners due to the inability of the air diffusers to provide complete mixing. If such is the case, the operator should tap the air supply line and install a diffuser in each corner. This will allow for better distribution of the available air supply and eliminate dead or septic pockets in the basin.

Foam Control

To control foam in the aeration tank or direct floating scum in the clarifier toward the scum box, a water spray system can be installed by the operator. The foam will require a spray with a larger force than would be necessary and desirable on a clarifier. For small aeration tanks, a shower nozzle located above the tank with the necessary piping is effective. For the clarifier, a nozzle, such as the type shown in the drawing with a fan spray, is effective in directing the scum.



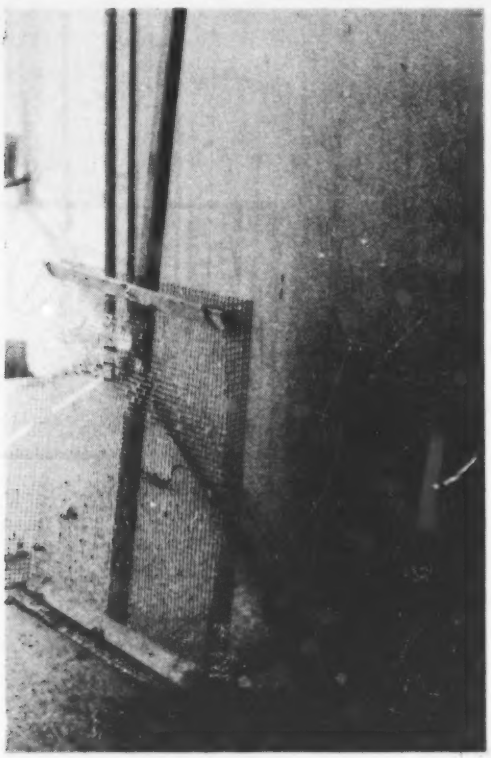
TOOLS

Sludge and Scum Scraper

One operator constructed a handy tool for scraping solids that accumulate in the inlet trough to the aeration tank. The following photos show the tool's construction and operation. If the solids were not occasionally stirred up, they would become septic and produce odors. This same tool can be used for scraping the sides of the clarifier.

Dip Net

Another device that every plant should have and that is easily constructed is a dip net to skim off the top of the water level. As shown in the photo, all that is necessary is the wood and screen. The handle should be long enough to reach any point on the water surface.



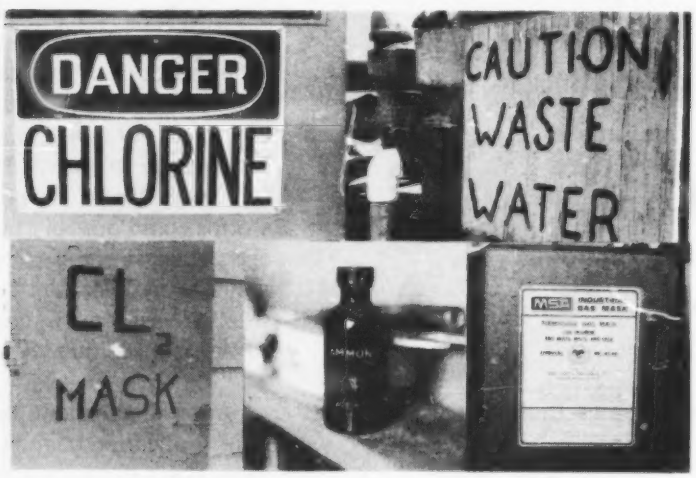
SECTION 2

SAFETY AND EMERGENCIES

GENERAL

Lost time, days, and even death is the result of not being concerned with applying the rules of safety to all activities involved in operating and maintaining a plant. Practicing "safety" is not just knowing what to do; it is a life-style. Personnel must not only acquire this "life-style," but must also know what to do if an accident occurs.

Sewage treatment plant operators have one of the most hazardous of jobs. Their injury rate or number of disabling injuries per man-hour is four times the average of all industries. Daily exposure to physical injuries, body infections, noxious gases or vapors and oxygen deficiencies is an occupational hazard encountered at sewage treatment plants.



LABORATORY SAFETY

The handling of wastewater and numerous chemicals creates a potential hazard to the health and safety of individuals in the lab. Danger originates when lab workers fail to use caution in handling these materials, fail to read labels or fail to follow directions as to use and procedure. There always exists the possibility of inadvertent or accidental spills which will require immediate and specifically correct action to minimize a potential hazard. Inhalation of vapors must be avoided since many chemicals or compounds are dangerous in this respect. In summary, it can be said that most hazards caused in the lab result from inattention, carelessness, and poor housekeeping.

CHLORINE SAFETY

Since chlorine usage is common to most treatment plants and due to its hazardous nature, some safety precautions regarding its use warrant mention. Chlorine gas affects the respiratory system and can cause burns. In any chlorine atmosphere use short, shallow breathing; recovery depends on the amount of chlorine inhaled. For more information on chlorine safety and first aid, see:

Chlorine Manual

By: The Chlorine Institute, Inc.
342 Madison Avenue
New York, New York 10017
Price: $0.75

EMERGENCIES

Effects of Weather

Freezing: All outside hose bibs should have underground drain capability in order to dewater the faucets during extreme freezing conditions. It will be necessary to check other portions of the plant which may be subject to freezing due to water splashing on mechanical equipment. If faucets are not self-draining, leave hose running into tank at a rate fast enough to prevent freezing.

High Winds: The major problem presented by windstorms could possibly be blowing debris, such as leaves, sticks, and paper from the surrounding area into the clarifier. This material could cause plugging of pumps, and the operator should check the pumping operation following windstorms to verify that sludge lines are open.

Emergency Resources

Warning System: Some of the larger plants may have a visual indication of the operating status of all equipment shown on a panel located in the control room. The control panel has two major functions—one is to show the status of all the operating equipment that is tied to the panel electrically, and the second is to sound an audible alarm and show visually which piece of equipment is in alarm condition. Some operators have installed a flashing red light at a high point around the plant connected to critical circuits such that when they are not energized the light flashes. Local police, or an obliging neighbor, can then notify the operator that a problem exists.

Standby Equipment: The operator should either have on site, or know where to obtain on short notice, a gas-driven pump. This allows the operator to handle emergency pumping needs during power failures or equipment breakdown.

Chemical Supplies: To ensure an adequate supply of chlorine at all times, the plant operating policy should be to reorder chlorine so as to always have at least two weeks supply and preferably 30 days supply on hand.

Security: Plants should be protected by a chain link fence around the periphery of the property with a locked entrance gate. External lighting should be provided and controlled by a light detector to automatically control the on-off function of the lights.

In regard to safety equipment, operators must be familiar with the location and use of the first aid kit, fire extinguishers, gas mask, and other items necessary in an emergency situation. A list of minimum emergency equipment follows:

- One 16-foot ladder
- One gas-driven, portable pump
- Fire extinguishers
- One first aid kit
- One special breathing apparatus
- One heavy-duty flashlight
- One chlorine leak repair kit

Emergency Notification

An emergency notification schedule such as the one presented below should be developed and posted at the plant and at the city's water and sewage works office or at the office of the treatment plant owner.

	TELEPHONE NUMBER
INJURY	
Fire Department	
Ambulance	
Hospital Emergency Room	
Poison Center	

	TELEPHONE NUMBER
FIRE-EXPLOSION-CHLORINE	
Fire Department	
Local Police	
County Sheriff	
State Patrol	
Local Chlorine Supplier	
UTILITIES	
Power Company	
Communication (Telephone)	
Water	
TOXIC SPILLS	
State Pollution Control Agency	
County Health Department	
RESPONSIBLE PLANT PERSONNEL	
Operator	
Relief Operator	
Person In Charge of Collection System	

SECTION 3

PLANT MANAGEMENT

PLANT OWNER

The owner may be the individual who actually purchased the package plant, the governing board of a sewerage agency, the city manager or city council. It is the individual or group of individuals that the operator is ultimately responsible to and who have the authority to make policy decisions in regard to the treatment plant.

The owner of a package sewage treatment plant has the responsibility of providing an operator who is conscientious, in good physical condition, and is capable of operating and maintaining the treatment plant after being provided proper instruction and orientation. The orientation period might initially require the full-time duties of the operator.

If the current operator leaves the employ of the owner, it is the owner's responsibility to obtain immediate replacement. The replacement should be provided with proper training to make up any possible deficiency.

The owner should encourage opportunities for plant personnel to expand their knowledge by attendance at meetings, short schools, special training courses, and utilizing other opportunities for increasing their technical competence.

The owner has the responsibility to establish a salary level scale that encourages tenure of trained and experienced personnel.

It is the responsibility of the owner to obtain from the appropriate regulatory agency any permit required for operation of the plant.

The owner is ultimately responsible for the performance of the treatment plant. To maintain such performance, the owner is responsible for general supervision of the operator, in addition to supplying him or her with all necessary tools, materials, and parts for proper plant operation and maintenance. It is also the responsibility of the owner to provide adequate funds for plant expansion as needed.

PLANT OPERATOR

The plant operator is responsible for the conscientious and proper operation and maintenance of the plant. This includes maintenance of buildings, grounds, and equipment.

The operator is responsible for maintaining a safe working environment and being safety conscious in his or her actions.

The operator is required to make those tests and observations required for the proper operation of the plant and to satisfy the appropriate reporting agency regulations. All results should be made known to the owner in terms that can be easily understood.

The operator must have the ability to interpret laboratory tests and apply their results to the operational control of the treatment plant.

The operator is responsible in notifying the owner as to the need for tools, parts, and supplies. Sufficient notice should be given so that such items will be available when needed.

The operator has the responsibility to become fully acquainted with the plant and the treatment process used. He should take advantage of training offered by the regulatory agency, manufacturer-supplier or local community college.

APPENDICES

APPENDIX A

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U.S. Environmental Protection Agency. ***Operational Control Procedures for the Activated Sludge Process***. 330/9-74-001 a, b, and c.

Part I — Observations
Part II — Control Tests
Part IIIA — Calculation Procedures

National Training and Operational Technology Center, Cincinnati, Ohio 45268.

(This material is also available in slide/tape format from this source.)

APPENDIX B

GLOSSARY

Absorption – A process in wastewater treatment by which organic material is consumed by a microorganism by passing the material through the cell of the microorganism.

Adsorption – The sticking of a solid in the wastewater to the surface of the microorganism.

Aerobic – A condition in which "free" or dissolved oxygen is present in the aquatic environment.

Anaerobic – A condition in which "free" or dissolved oxygen is **not** present in the aquatic environment.

Biochemical Oxygen Demand (BOD) – A measurement of the amount of oxygen required by the microorganisms to metabolize or digest the organic material in the wastewater.

Contact Tank – The tank in the contact-stabilization plant that receives wastewater and reaerated return sludge. Adsorption takes place here.

Dissolved Solids – Consists of organic and inorganic material that is present in true solution in the wastewater.

Grit – The heavy mineral material present in wastewater such as sand, eggshells, gravel, and cinders.

Inorganic Waste – Waste material such as sand, salt, iron, calcium, and other mineral materials which are not converted in large quantities by microorganism action. Inorganic wastes are chemical substances of mineral origin and may contain **carbon** and **oxygen**.

Microorganisms – Microscopic living objects which require energy, carbon, and small amounts of inorganic elements to grow and multiply. They get these requirements from the wastewater and the sun and in doing so help to remove the pollutants from the wastewater.

Mixed Liquor – Used to refer to the mixture of wastewater and return activated sludge in the aeration tank of an activated sludge system.

Overaerated – Sludge which has long periods in the aeration tanks with dissolved oxygen at 4 mg/L and above.

Overoxidized – Sludge which passes through the aerator and clarifier many times in one day due to high return rates.

Organic Waste – Waste material which comes from animal or vegetable sources. Organic waste generally can be consumed by bacteria and other small organisms. Organic wastes contain mainly carbon and hydrogen along with other elements.

pH – A term used to express the intensity of the acid or alkaline sources. A pH of 7 is considered neutral, with acidity increasing as the pH decreases. Normal pH for wastewater treatment is 6.5 to 7.5.

Septic – A condition produced by the growth of anaerobic organisms. If severe, the wastewater turns black, giving off foul odors and creating a heavy oxygen demand.

Settleable Solids – That matter in wastewater which will not stay in suspension during a preselected settling period.

Sludge – The settleable solids separated from the liquid during clarification.

Sludge Age – The theoretical length of time that a particle of activated sludge will remain in the aeration system.

Sludge Digestion – A process by which organic matter in sludge is gasified, liquified, mineralized, or converted to a more stable form by anaerobic or aerobic organisms.

Stabilization Tank – The tank in the contact-stabilization plant that receives return sludge from the clarifier for more aeration (reaeration). Absorption takes place here.

Supernatant – Liquid removed from settled sludge. Supernatant commonly refers to the liquid between the sludge on the bottom and the scum on the surface of any settling tank.

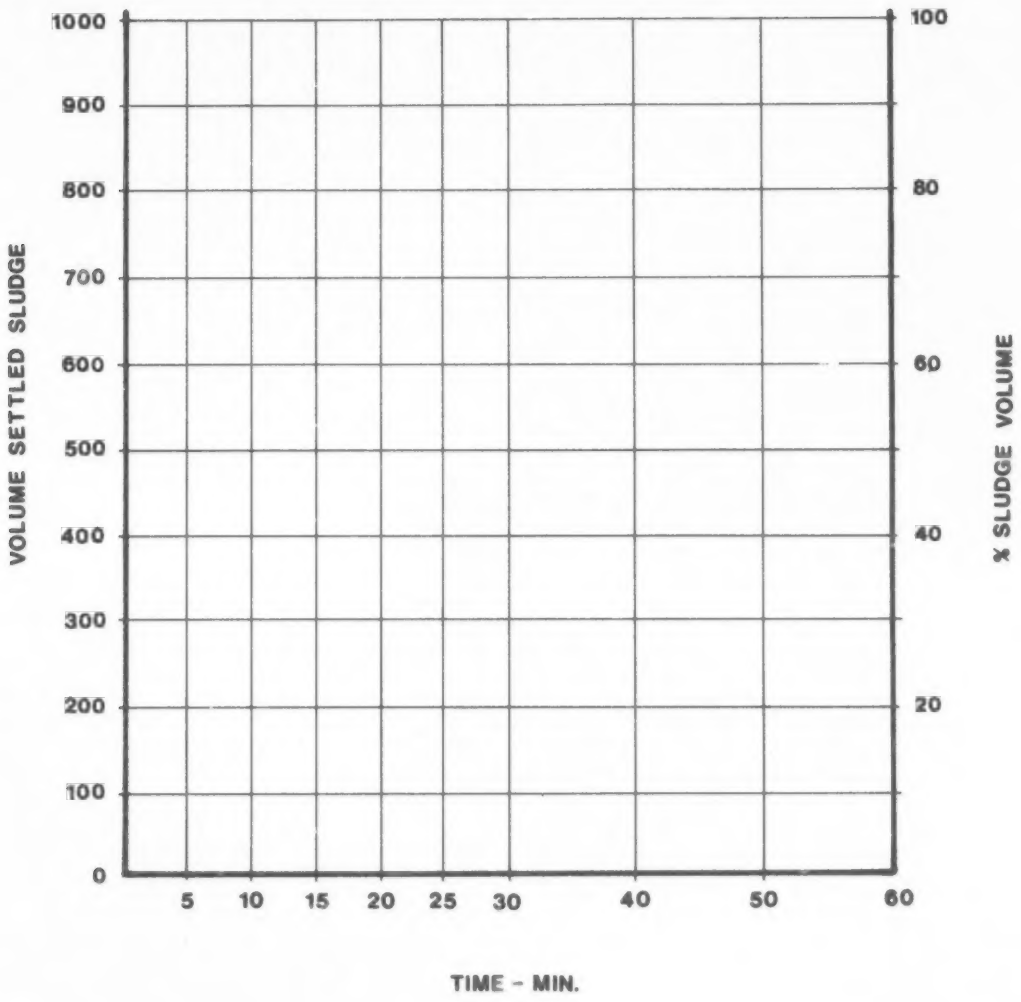
Suspended Solids – Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids and are largely removable by filtering.

APPENDIX C
OPERATION AND MAINTENANCE SCHEDULE

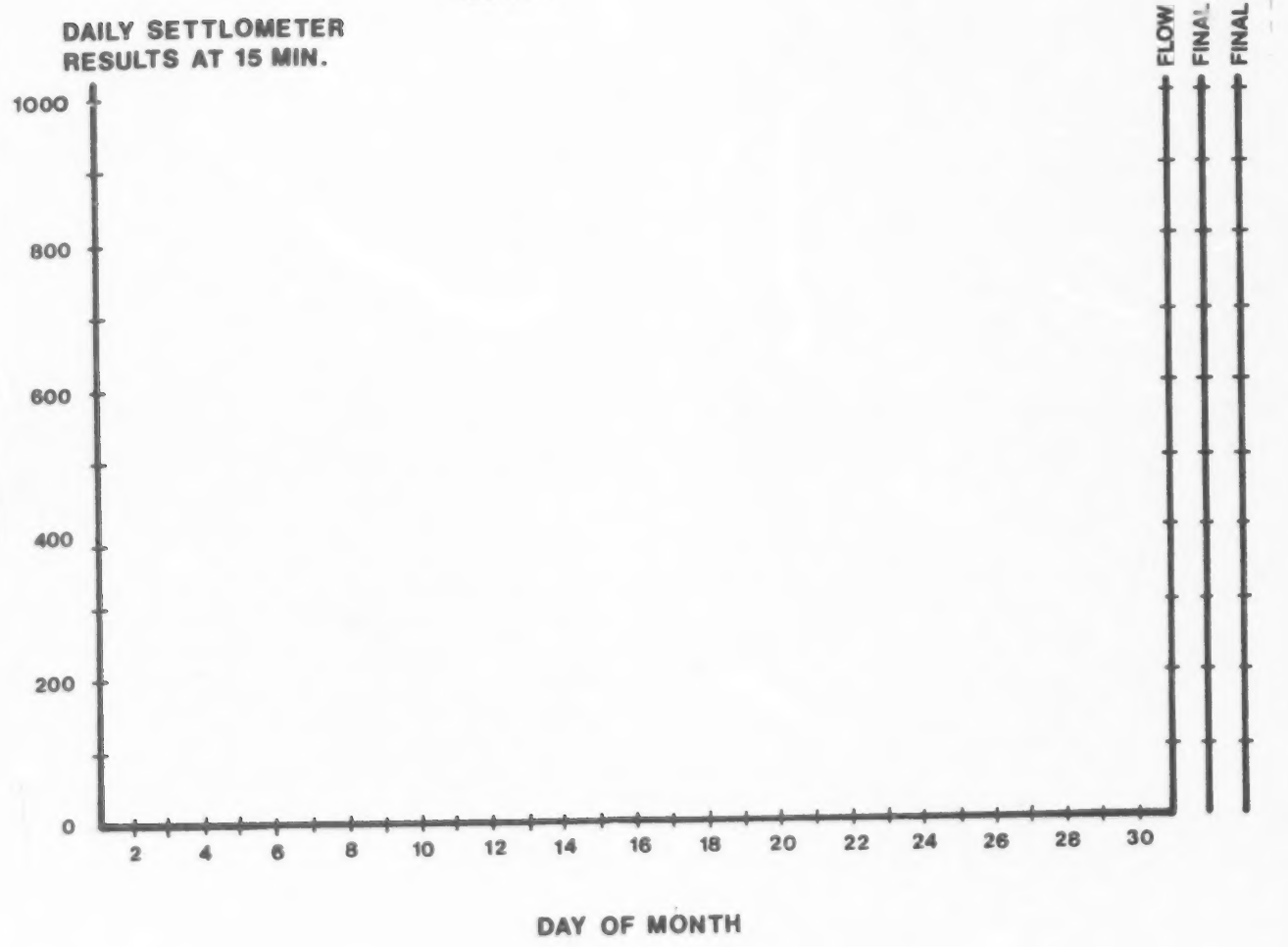
Operational and Preventive Maintenance	Frequency						
	Daily	Wk.	Mo.	3 Mo.	6 Mo.	Yearly	As Necessary

APPENDIX D
SETTLOMETER GRAPH

SETTLOMETER
DATE:



APPENDIX E
MONTHLY TREND GRAPH
MONTH:



APPENDIX F
FLOW RECORDS

MONTH: _____

Day of Month	Totalizer Reading	Daily Flow	Comments
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
31			
Total			
Average			

APPENDIX G
METRIC EQUIVALENTS

METRIC CONVERSION TABLES

Recommended Units

Description	Unit	Symbol	Comments	English Equivalents
Length	meter	m	*Basic SI unit*	39.37 in. = 3.28 ft = 1.09 yd
	kilometer	km		0.62 mi
	millimeter	mm		0.03937 in.
	centimeter	cm		0.3937 in.
	micrometer	μm		$3.937 \times 10^{-3} = 10^{3}$A
Area	square meter	m^2		10.744 sq ft = 1.196 sq yd
	square kilometer	km^2		6.384 sq mi = 247 acres
	square centimeter	cm^2		0.155 sq in.
	square millimeter	mm^2		0.00155 sq in.
	hectare	ha	The hectare (10,000 m^2) is a recognized multiple unit and will remain in international use.	2.471 acres
Volume	cubic meter	m^3		35.314 cu ft = 1.3079 cu yd
	cubic centimeter	cm^3		0.061 cu in.
	liter	L	The liter is now recognized as the special name for the cubic decimeter	1.057 qt = 0.264 gal = 0.81×10^{-4} acre-ft
Mass	kilogram	kg	*Basic SI unit*	2.205 lb
	gram	g		0.035 oz = 15.43 gr
	milligram	mg		0.01543 gr
	tonne	t	1 tonne = 1,000 kg	0.984 ton (long) = 1.1023 ton (short)
Time	second	s	*Basic SI unit*	
	day	day	Neither the day nor the year is an SI unit but both are important.	
	year	yr or a		
Force	newton	N	The newton is that force that produces an acceleration of 1 m/s^2 in a mass of 1 kg.	0.22481 lb (weight) = 7.5 poundals

Recommended Units

Description	Unit	Symbol	Comments	English Equivalents
Velocity				
linear	meter per second	m/s		3.28 fps
	millimeter per second	mm/s		0.00328 fps
	kilometers per second	km/s		2.230 mph
angular	radians per second	rad/s		
Flow (volumetric)	cubic meter per second	m^3/s	Commonly called the cumec	15,850 gpm = 2,120 cfm
	liter per second	L/s		15.85 gpm
Viscosity	poise	poise		0.0672 lb/sec ft
Pressure	newton per square meter	N/m^2	The newton is not yet well known as the unit of force and kgf cm^2 will clearly be used for some time. In this field the hydraulic head expressed in meters is an accepta able alternative.	0.00014 psi
	kilonewton per square meter	kN/m^2		0.145 psi
	kilogram (force) per square centimeter	kgf/cm^2		14.223 psi
Temperature	degree Kelvin	K	*Basic SI unit*	$°F = \frac{9}{5}°C + 32$
	degree Celsius	C	The Kelvin and Celsius degrees are identical. The use of the Celsius scale is recommended as it is the former centigrade scale.	
Work, energy, quantity of heat	joule	J	1 joule = 1 N·m	2.778×10^{-7} kw-hr = 3.725×10^{-7} hp-hr = 0.73756 ft-lb = 9.48×10^{-4} Btu
	kilojoule	kJ		2.778 kw-hr
Power	watt	W	1 watt = 1 J/s	
	kilowatt	kW		
	joule per second	J/s		

Application of Units

Description	Unit	Symbol	Comments	English Equivalents
Precipitation, run-off, evaporation	millimeter	mm	For meteorological purposes it may be convenient to measure precipitation in terms of mass/unit area (kg/m^3). 1 mm of rain = 1 kg/sq m	
River flow	cubic meter per second	m^3/s	Commonly called the cumec	35.314 cfs
Flow in pipes, conduits, channels, over weirs, pumping	cubic meter per second	m^3/s		
	liter per second	L/s		15.85 gpm
Discharges or abstractions, yields	cubic meter per day	m^3/day	1 L/s = 86.4 m^3/day	1.83×10^{-3} gpm
	cubic meter per year	m^3/yr		
Usage of water	liter per person per day	L/person day		0.264 gcpd
Density	kilogram per cubic meter	kg/m^3	The density of water under standard conditions is 1,000 kg/m^3 or 1,000 g/L	0.0624 lb/cu ft

Application of Units

Description	Unit	Symbol	Comments	English Equivalents
Concentration	milligram per liter	mg/L		1 ppm
BOD loading	kilogram per cubic meter per day	kg/m^3 day		0.0624 lb/cu ft day
Hydraulic load per unit area, e.g. filtration rates	cubic meter per square meter per day	m^3/m^2 day	If this is converted to a velocity, it should be expressed in mm/s (1 mm/s = 86.4 m^3/m^2 day).	3.28 cu ft/sq ft
Hydraulic load per unit volume, e.g. biological filters, lagoons	cubic meter per cubic meter per day	m^3/m^3 day		
Air supply	cubic meter or liter of free air per second	m^3/s		
		L/s		
Pipes				
diameter	millimeter	mm		0.03937 in.
length	meter	m		39.37 in. = 3.28 ft
Optical units	lumen per square meter	lumen/m^2		0.092 ft candle/sq ft

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